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SKYLAB EXPERIMENT S063 UV AIRGLOW HORIZON PHOTOGRAPHY.(U)

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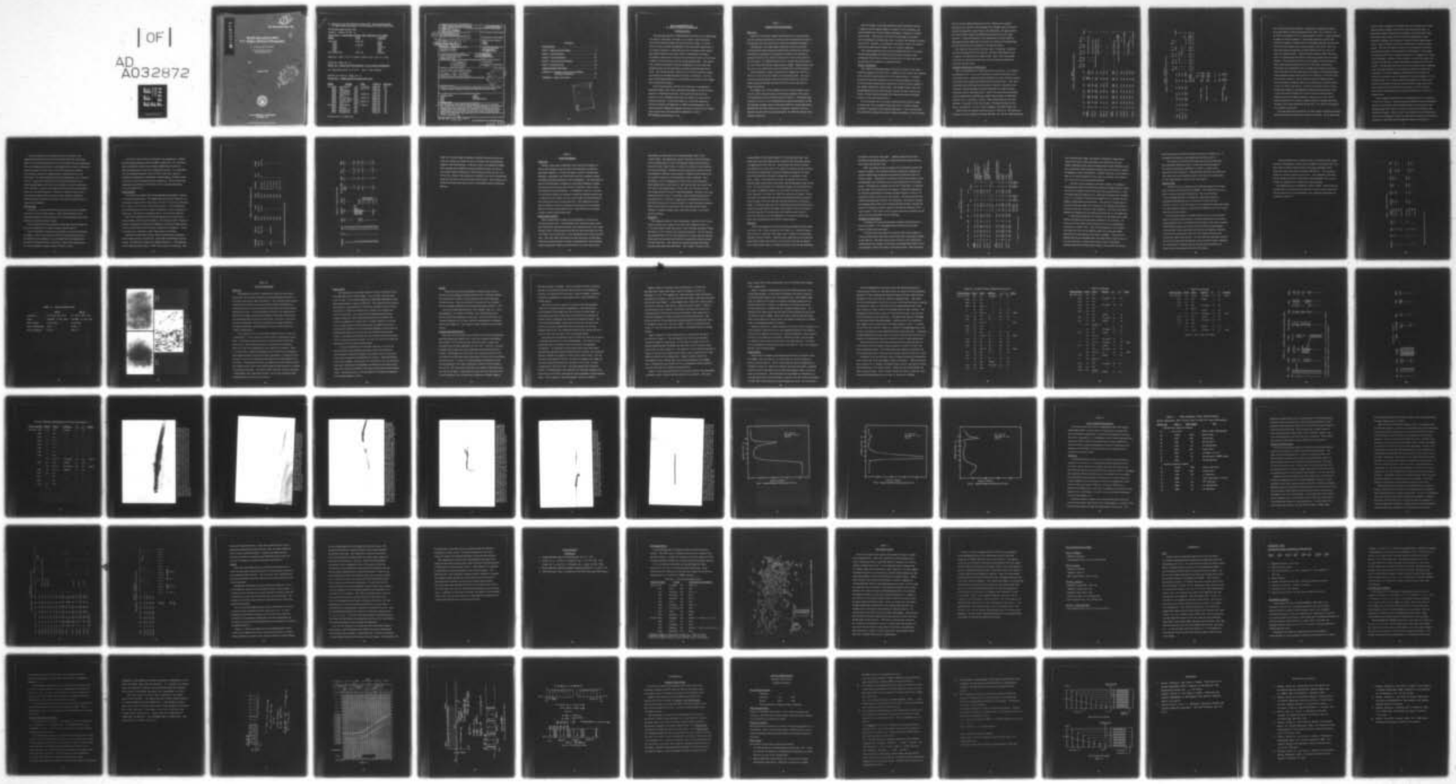

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NRL Memorandum Report 3381

Skylab Experiment S063
UV Airglow Horizon Photography

D. M. PACKER AND I. G. PACKER

Rocket Spectroscopy Branch
Space Science Division

October 1976

NAVAL RESEARCH LABORATORY
Washington, D.C.

To: Distribution list for NRL Memorandum Report 3381, "Skylab Experiment S063, UV Airglow Horizon Photography," by D.M. Packer and I.G. Packer, October 1976.

The following changes should be made:

Addenda (Pages 35-36) to

Table VIII. Digitized Auroral Data Deposited at NSSDC

FRAME	DATE	TIME(UT)
130-3126	9/11/73	1712
3140	"	2325
3144	9/12/73	1627
3145	"	1758:30
3146	"	1800
3151	"	1936
200-7648/7655	2/07/74	unknown

Exposure times for all frames range from 1 sec to 4 sec.

Addendum (Page 37) to

Table IX. Digitized Photographs of the Lower Atmosphere

All exposures made on 2/7/74. Exact time unknown.

Addenda and Errata (Page 57) to

Table XII. Comet Kohoutek Digitized Data

FRAME	FILTER		DATE	TIME(UT)	EXP(Sec)
177-5947	whitelight	A1)	12/09/73	2054:50	270
5953	3581 Å	(A3)	12/17/73	1695:10	30
5954	whitelight	(A1)	"	1700:02	03
5955	OH(3090 Å)	(C3)	"	1700:51	90
5957	whitelight	(A1)	12/20/73	0150:21	01
5958	3581 Å	(A3)	"	0150:44	30
5962	whitelight	(A1)	12/21/73	2336:35	01
5964	C_2 near 4700 Å	(C2)*	"	2338:22	30
5969	whitelight *	(A1)*	12/22/73	1643:00	01
5970	3581 Å *	(A3)*	"	1644:22	15
178-5987	whitelight	(A1)	1/09/74	0041:00	01
5988	3581 Å	(A3)	"	0041:41	30
5991	OH(3090 Å)	(C3)	"	0046:40	60
5996	whitelight	(A1)	"	2054:16	15
6000	OH(3090 Å)	(C3)	"	2058:22	90

*Correction to Table XII

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9 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 3381	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 SKYLAB EXPERIMENT S063 UV AIRGLOW HORIZON PHOTOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 D. M. Packer and I. G. Packer Donald Irene p78		8. CONTRACT OR GRANT NUMBER(s) T-88583 H-18200B
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NRL Problem A01-38 NASA, DPR-T-88583, O
11. CONTROLLING OFFICE NAME AND ADDRESS National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058		12. REPORT DATE 11 October 1976 13. NUMBER OF PAGES 81
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 81p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

14 NRL-MR-3381

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Prepared as a User's Guide for data deposited in the National Space Science Data Center, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Atmospheric physics
Airglow
Ozone
Comet
Noctilucent clouds
Aurora
Ultraviolet
Solar particle radiation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Skylab space station offered a unique opportunity for man-in-space to study Earth's upper atmosphere from an average 435 km altitude. Experiment S063 made use of 35 mm cameras equipped with various narrow-band filters in the visible and middle ultraviolet spectral range to photograph airglow, aurora and daytime ozone concentrations. Comet Kohoutek was also photographed through various lenses and filters. The present report details the experiment and data deposited at the National Space Science Data Center for use by any scientist who might wish to use the data in further studies.

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S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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CONTENTS

SKYLAB EXPERIMENT S063
UV AIRGLOW HORIZON PHOTOGRAPHY

INTRODUCTION

The principal objective of Skylab Experiment S063 was to photograph the airglow, especially at twilight, in a number of spectral bands within the visible and middle ultraviolet spectral range. A second objective was to attempt photography of the ozone layer using some of the airglow equipment. Advantage also was to be taken of the unique opportunity offered by the space station to photograph such upper atmospheric phenomena as auroras and noctilucent clouds, the existence of either at any given place and time being unpredictable. The experiment scope was extended to include photography of Comet Kohoutek through various narrow band filters provided by Skylab Experiment T025. The overall problem required man to select and follow targets accurately with tracking equipment and thus, incidentally, add to the body of knowledge gained about man's abilities to perform in the weightless environment of space.

All of the phenomena, except Comet Kohoutek, investigated by Experiment S063 occur in the terrestrial atmosphere and are powered directly or indirectly by the sun. The results of each objective, however, are not influenced by those of the others, so each will be treated separately. On the other hand, all of the data considered worthy of analysis was digitized on a PDS microdensitometer, and instructions for reading the magnetic tapes are common for all of them. These instructions are presented in Appendices A and B.

Note: Manuscript submitted September 15, 1976.

PART I

Airglow Horizon Photography

Objectives

Objectives of the S063 airglow experiment were to study the altitude and intensity variations of certain airglow emissions by means of photography from the spacecraft at various geomagnetic latitudes.

Photographs of the night airglow had been made from Gemini and Apollo spacecraft using broad-band filters and Maurer cameras. Tracking was maintained for exposures as long as two minutes by pointing the spacecraft, with fine adjustment of the camera itself by the astronauts. The Skylab objective was to extend the measurements into the ultraviolet spectral range and into twilight. High latitude coverage came as an added feature with the Skylab orbit of 50° inclination.

The principal UV airglow emission in the region from 2000 Å to 3000 Å is from molecular oxygen in the Herzberg bands. The most intense and spectrally pure part of this band system near 2600 Å is easily measured through interference filters and was selected for study from Skylab.

At twilight, the 3914 Å radiation from the ionized nitrogen molecule is a short-lived emission, decreasing in intensity after sunset at emission altitude by a decade every few minutes. The Skylab filter centered at λ3914 Å of 45 Å halfwidth had a peak transmittance of 30%. Photography through a filter of this band width from the ground cannot differentiate the line radiation from continuum emission, but from Skylab's position above the emitting layers, the different species were spatially separated.

Also at twilight, as the sun leaves the upper atmosphere and the F region of the ionosphere begins to change in electron density, the 6300 Å airglow from atomic oxygen undergoes a transition in altitude and intensity. The formation of electrons and oxygen ions ceases, and recombination processes take over. A study of the twilight processes from Skylab, therefore, was planned to include the 3914 Å, the 6300 Å, and the associated atomic oxygen 5577 Å, airglow radiations.

The airglow objectives were further modified after SL-3 to include infrared photography of the hydroxyl (OH) airglow because of the availability of the IR film and the perceived need for wider pass-band photography of the airglow, as explained below.

Method of Operation

The method of obtaining airglow data was to secure 35-mm photographs through narrow band filters. Guidance of the camera was required of an astronaut during exposures up to 64 seconds long. A tracking bracket was therefore designed to move camera and guide telescope as the astronaut maintained an illuminated reticle in position tangent to the visible, unfiltered, airglow band. The twilight airglow was to be photographed from the solar scientific airlock at orbital sunrise and sunset, thereby taking advantage of the spacecraft sunward pointing controls in the solar inertial mode.

The unfortunate loss of the solar scientific airlock (SAL) because of deployment of the sunshade through and over it, caused a change in method of operation of the airglow experiment. The anti-solar SAL was utilized by adapting the airglow tracking mechanism to the articulated

mirror system (AMS) of Experiment S019. Whereas the original experiment was limited to photography of the twilight layers of airglow because of geometric constrictions at the solar SAL, the night airglow also came within range of the AMS when extended in the anti-solar direction. Practical operation of the experiment was thus aided by allowing the entire night side of an orbit to be utilized for photography, and the objectives were broadened to include this ability.

The field-of-view with the AMS was about 7.5 degrees, compared with the 30-degree field of the camera, and hence represented a loss of angular coverage from the original plan. Also, there was insufficient time for training the observers in the increased complexity of operating the experiment.

Analysis of Experiment Performance

S063 was scheduled to be performed on SL-3 and SL-4. The airglow experiment for SL-3 was to be comprised of several hand-held, hence necessarily short, exposures during twilight from glass windows mounted in the Structural Transition Section (STS) of the spacecraft. After three operations were performed in this manner, however, permission was obtained to utilize the AMS at the anti-solar SAL for longer duration exposures and for ultraviolet work. None of the hand-held photographs made through filters recorded any airglow data because of insufficient exposure time. One photo, however, taken without filter at that time did show a composite of the visual bands. The digitized data for this frame, number SL3-131-3191, are on magnetic tape (MT) number 26.

Table I lists the airglow operations for SL-3 and SL-4. Six operations during SL-3 were performed utilizing the AMS, but one was a familiarization

Table I

AIRGLOW - OPERATIONAL CHRONOLOGY and DATA LISTING

DATE	MD	DOY	GMT	to GMT	REV.	MODE	CASS.	2500A Sched	2500A Perf	3914A Sched	3914A Perf	5577A Sched	5577A Perf	6300A Sched	6300A Perf	IR Sched	IR Perf	USABLE
SL-3																		
08-14-73	18	226	1412	1414	1327	Hand Held	BV-13			4	4	(35mm lens)(1 visible pix)						1
	18	226	2158	2201	1332	HH	BV-13			4	2							0
08-19-73	23	231	1401	1413	1399	HH	BV-13			8	0	(camera malf.-no pix)						0
08-27-73	31	239	1307	1330	1514	AMS		(familiarization run-no exposures made)										
	31	239	1440	1519	1515	AMS	BV-14					6	6	6	6			0
												(used UV lens at F/16.)						
08-28-73	31	240	0133	0212	1522	AMS	BV-14					5	5	7	7			0
08-31-73	35	243	2247	2323	1577/8	AMS	BV-14	6	5	4	4							0
09-01-73	36	244	0156	0231	1579/80	AMS	BV-15					6	6	6	6			4
SL-4																		
12-11-73	26	345	1730	1804	3048	AMS	BV-44					4	4	6	5			0
	26	345	1902	1937	3049	AMS	BV-44	6	6	2	2	(Used Vis lens w/UV)						0
12-15-73	30	349	1619	1652	3110	AMS	BV-44					4	4	6	6	(No camera		0
										timer-No reticle light-No voice tape)								
12-16-73	31	350	1405	1438	3118	AMS	IR-14									16	15	5
01-06-74	52	006	2124	2156	3427	AMS	BV-27					5	5	7	7(A/G not tracked)			0
01-09-74	55	009	1442	1511	3465	AMS	BV-28					5	5	7	5			0
												(not enuf exposure)						
	55	009	1748	1817	3467	AMS	IR-10									15	10	0
01-19-74	65	019	1733	1747	3611	AMS	BV-29					3	3	4	4(A/G not tracked)			0

Table I. Continued

AIRGLOW - OPERATIONAL CHRONOLOGY and DATA LISTING

DATE	MD	DOY	GMT	to GMT	REV.	MODE	CASS.	2500A Sched	2500A Perf	3914A Sched	3914A Perf	5577A Sched	5577A Perf	6300A Sched	6300A Perf	IR Sched	IR Perf		USABLE
01-19-74	65	019	1906	1921	3612	AMS	BV-29	9	9	(A/G not tracked)									0
01-23-74	69	023	1750	1811	3669	AMS	BV-49	7	6	6	6	(tracking poor)							0
01-29-74	75	029	1952	2006	3757	AMS	BV-40	5	5	3	3	3	3	3	3			2-Vis	2
	75	029	2259	2333	3759	AMS	IR-12									18	18		4
						SL-4 TOTALS		27	26	11	11	24	24	33	30	49	43	2-Vis	11
						SL-3 TOTALS		6	5	20	10	17	17	19	19	--	--	1-Vis	4
						TOTALS		33	31	31	21	41	41	52	49	49	43	3-Vis	15

		Sched	Perf
UV (2500A + 3914A)	SL-4	38	37
	SL-3	26	15
		64	52
Visible (5577 + 6300)	SL-4	59	56
	SL-3	36	37
		95	93
IR	SL-4	49	43

		Sched	Perf
TOTAL AIRGLOW	SL-4	146	136
	SL-3	62	52
TOTALS		208	188

run in which no film was exposed. During the remaining five runs a good distribution of filtered exposures was made: five at 2500 Å, ten at 3914 Å, seventeen at 5577 Å, and nineteen at 6300 Å. These operations brought out several problems. The twilight exposures could not be made near enough to twilight because of sunlight reflected and scattered into the mirror system from the solar panels of the ATM. Also, the seven good filtered exposures (on MT26) gained from the total of 57 were the longest exposed. These exposures showed neither the earth limb nor a background star field for reference measurement of airglow altitude. This resulted from the narrow bandpass of the interference filters used and the small field of view of the AMS, respectively. The filters were designed for use at twilight and properly would have restricted light from the bright lower atmosphere in those photographs, while exposing enough of the earth limb for reference. The narrowness of the filters, however, did not affect the amount of light received from the airglow emissions which were concentrated in spectral lines at 5577 Å, 6300 Å, and 3914 Å. An effort was made on SL-4 to work around this problem by scheduling the experiment during times close to full moon when the night side of earth would be bright enough to appear in the narrow-band exposures. Also on SL-4, some of the airglow exposures were made on infrared (IR) film (Kodak Type 2443) through a very broad-band filter (Wratten No. 12), which was available from another experiment.

The long exposures required for the night airglow emphasized another factor that would not have been a problem at twilight. As the spacecraft

moved in orbit, images of the airglow and earth horizon arcs rotated about the line-of-sight in both camera and tracking telescope. At spacecraft sunset, the horizon was tangent to the spacecraft Y-axis. The horizon then rotated slowly to become perpendicular to this position at midnight, and continued rotating to become again tangent to the Y-axis at sunrise, but curved in the direction opposite that at sunset. The rate of rotation varied with the inclination of the solar direction with respect to the spacecraft orbital plane, or beta angle, and position in the orbit, reaching a maximum of 5 degrees per minute around midnight. During a 64-sec exposure at small beta angle, this rotation was sufficient to cause appreciable smearing of the horizon images. The astronaut-observers on both missions used the capability of the tracking mechanism to be oriented in rotation to reduce this smearing. This was a significant achievement for the observers because the equipment was not designed for two-axis tracking. It was also found that, for a certain range of beta angles, the AMS mirror could be orientated such that the airglow horizon image would move very slowly across the field-of-view and with very little rotation. Such mirror configurations were used successfully for the last two airglow runs.

Twelve airglow operations were accomplished on SL-4, exposing a total of 136 frames. Some performance difficulties were encountered by the crew during the early operations when the camera timer and tracking sight reticle failed, but both of these were restored to use during the mission. Three or four of the operations also served as on-the-job crew training for each of two operators to acquire the necessary expertise to track with both the AMS and experiment hardware.

A major problem was encountered on SL-4, however, that apparently occurred with the first roll of film in NK-02, the electric drive 35-mm Nikon camera used for all the airglow and ozone exposures. The crew experienced difficulty in unloading the film, and all subsequent exposures made in NK-02 were out of focus; apparently resulting from the film, because of weightlessness, floating away from the focal plane. No useful airglow exposures through filters were obtained on SL-4. Most of the frames were not exposed adequately to distribute enough light in the out-of-focus images to record useful densities on the film, except the broadband IR exposures which were amply dense for correction purposes. Attempts to refocus several of the more heavily exposed infrared frames using computer techniques resulted in failure because the amount of correction required was too complex and irregular.

Data Analysis

From SL-3, seven useful filtered airglow pictures were obtained, all of them at 5577 Å night airglow. Some altitude profiles of the airglow distribution may be derived from these photographs but without reference to absolute altitude values.

The one hand-held frame exposed in white light shows the edge-on view of a composite of all visible airglow emission layers.

None of the 2500 Å exposures was adequate to record the presence of airglow. Since all but one of the 2500 Å were exposed for 64 sec, the maximum time available, it is concluded that this radiation was too faint to be detected by the experiment. None of the exposures on SL-4 were adequate to obtain images at 2500 Å, either.

At 3914 Å, none of the SL-3 exposures was satisfactory. During the best exposed sequence with the AMS on August 28, 1973, the astronaut noted that the horizon was rotating rapidly about his line-of-sight and attempted to correct by rotating the camera. It is concluded that the maximum exposure time of 64 sec at this time, plus the additional complication of insufficient tracking ability, resulted in lack of detection of 3914 Å radiation by the experiment. Several hand-held exposures made with the 3914 Å filter on SL-3 recorded the bright lower atmosphere only.

Digitized Data

Table II lists the airglow film being deposited with NSSDC, together with exposure information. The digital data are listed in Table III. All the airglow exposures were made with a 55 mm, F/1.2 lens on 2485 type film. Frame 131-3191 was a hand-held exposure. Seven independent microdensitometer scans were made of this frame to aid in reduction of data noise. The data are recorded in files 1-7 as listed in Table III.

The 5577 Å exposures were made through the Articulated Mirror System (AMS), with the earth limb dark. The column headed "Location" contains coordinates for the point of tangency of the line of sight with the 100-km altitude level above the earth, midway in the exposure. "Time" is starting time of exposure, while "Exp" gives the duration.

Appendices A and B give further details concerning the exposures and the digitized data, respectively. Data under the headings of all but column 1 in Table III are found in an ASCII-coded label at the beginning of each digital record on tape. "Date" was the date of recording. Scan

TABLE II DIGITIZED AIRGLOW FILM

CASSETTE	SER NO	FRAME	DATE	TIME	LOCATION	EXP.	FILTER
BV-13	SL3-131-	3191	8/14/73	1415UT	*	2 sec	none
BV-14	SL3-132-	3219	9/1/73	0141	30°N 45°W	64	5577 Å
"	"	3222	"	0154	15 N 15 W	"	"
"	"	3224	"	0204	20 S 17 E	"	"
BV-15	SL3-133-	3233	"	0209	15 N 43 W	"	"
"		3235	"	0215	0 N 30 W	"	"
"		3236	"	0218	7 S 20 W	"	"
"		3238	"	0224	26 S 9 W	"	"

*Looking southeast over the Phillipine Islands

TABLE III AIRGLOW DIGITAL DATA

File No.	MT	File	Date	Subject	Frame	No. Pts./Rec.	Recs.	Slit	Rate
1	26	F 02	3-02	WAG	131-3191	1024 x	100	5 x 200	S 128
2	"	F 03	"	"	"	2048 x	"	"	"
3	"	F 04	"	"	"	"	"	"	"
4	"	F 05	"	"	"	"	"	"	"
5	"	F 06	"	"	"	"	"	"	"
6	"	F 07	"	"	"	"	"	"	"
7	"	F 08	"	"	"	"	"	"	"
10	"	F 11		CALWEDGE 3#1		64 x	64	5 x 200	S 128
11	"	F 12		CALWEDGE #2		"	"	"	"
12	"	F 13		REFWEDGE		"	"	"	"
14	"	F 15	3-03	CALWEG	3-133-1	256 x	64	25 SQ	S 128
15	"	F 16	3-03	CALWEG	3-133-2	"	"	"	"
16	"	F 17	3-03	REFWEG		"	"	"	"
17	"	F 18	"	AG	133-3238	1024 x	112	5 x 100	S 128
18	"	F 19	"	"	" 3236	"	"	"	"
19	"	F 20	"	"	" 3235	"	"	"	"
20	"	F 21	"	"	" 3233	"	"	"	"
21	"	F 22	"	"	132-3224	"	"	"	"
22	"	F 23	"	"	" 3222	"	"	"	"
23	"	F 24	"	"	" 3219	"	"	"	"
24	"	F 25	"	CALWEG	3-131-1	128 x	64	5 x 100	S 128
25	"	F 26	"	"	" 2	"	"	"	"
26	"	F 27	"	"	3-132-1	"	"	"	"
27	"	F 28	"	"	" 2	"	"	"	"

steps of 5 microns along a scan line, with 200 microns between scan lines were made, the 5x200 micron slit oriented with long dimension tangent to the earth horizon. Contrary to plan, the calibration wedges were scanned with a different-sized slit than the frames of interest (25 microns square instead of 5 x 200 microns) for film roll SL3-133, files 14-20. Data for the wedges were obtained in 25 micron increments along the scan lines, with 25 microns between lines. The D-logE curves plotted from these data should serve in calculating relative intensities, however.

PART II

Ozone Photography

Objectives

Ozone, a very minor constituent of the earth's atmosphere, is vital to the ecology of man by virtue of its absorption of harmful ultraviolet radiation. It covers the globe, varies in concentration diurnally, seasonally, and with latitude, and its movements reflect worldwide circulation patterns in the stratosphere. The importance of ozone to meteorology is evidenced by increased emphasis on global measurements from the ground and from satellites, which provide ideal platforms for observations. It is difficult, however, to assess the extraneous influence in the data collected by unmanned spacecraft, of reflections from clouds, the sea, and all other terrestrial features that underlie the area of ozone observed. This experiment investigated a different method of obtaining measurements of the changing patterns of ozone concentration from a spacecraft and of detecting clouds of ozone if such indeed exist.

Experimental Method

The procedure was to make three photographs of a given area beneath the spacecraft. One photograph was exposed through a filter that transmitted radiation within the ozone absorption band, the second through a filter transmitting just beyond the long wavelength end of the ozone band, and the third was a color photograph of the same observed area. The color photo data depict the types and areas of underlying cloud and terrain features; the longer wavelength filter data establish relative ultraviolet reflection characteristics of these features and,

importantly, provide data on the long wavelength "leak" of the "ozone" filter. By subtraction, picture element by picture element, of the combined data of the two photographs outside the ozone band from that of the "ozone" data, a measure of relative ozone concentration may be obtained. Results from this analytical procedure may be extrapolated to interpret long exposures of adjacent areas where only one ultraviolet and one color photograph could be obtained. Here, alternately, one UV photograph was made in the ozone absorption band together with a color picture, then another pair was made in the "off-ozone" and visible bands. In this case, the color film serves as a bridge between the two UV band photographs. Because of the long exposures required (up to 16 seconds), and the high ground speed of the spacecraft (7.5 km/sec), image motion compensation had to be provided to keep the UV camera pointed at a target during an exposure. This was done with a simple device that permitted the astronaut-observer to track his target with a telescope attached to a movable camera carriage.

Equipment

The equipment used for ozone photography consisted of two 35-mm format electric drive cameras with electronic exposure timers, a 2 1/2 power optical sight with reticle, and a tracking carriage on which the sight and "UV" camera were mounted at the SAL. The UV camera was equipped with a 55-mm focal length F/2.0 quartz-calcium fluoride achromatic lens and was used with the two ultraviolet filters mounted in front of the lens. This camera was loaded with high speed black and white film (type 2485-ASA 4000). The "visible" camera, with a

standard Nikon 55-mm focal length F/1.2 lens and haze filter, was loaded with color film (ASA 64) and mounted in the wardroom window, co-aligned with the UV camera. The altitude of the area of interest was expected to be near 30 km, the region of maximum ozone concentration and the average depth to which the radiation passed by the ozone filter would penetrate; whereas tracking was on a ground or cloud target. Thus, as the spacecraft moved, the parallax of the 30 km altitude region would result in blurring of the photographed image of this area. To circumvent this, the tracking carriage was provided with two arc tracks, of different radius, one over which the sight was driven by the observer, the other over which the camera was carried. These radii were so selected that the camera remained focussed on target at 30 km altitude, while the telescope was kept trained on a terrestrial target. Ultraviolet exposures were initiated automatically during tracking by the moving camera carriage, and actuation of the color camera occurred when the UV camera was at the nadir position. Both UV and color exposures were terminated by the camera timers and the films were transported by the electric camera drives.

Operation

Ozone photography was performed during daylight when the spacecraft was in the Z-local vertical (Z-LV) mode, i.e., when the experiment could view the earth at the nadir from a window in the anti-solar scientific airlock (A-SAL). Operation was restricted to times when the angle between nadir and direction to the sun was less than 60 degrees and for beta angles within $\pm$ 40 degrees because of the strong dependence

of exposure time upon solar angle. Lighting conditions were also favorable at beta angles within ± 10 degrees when the spacecraft was in the solar inertial (SI) mode.

After the equipment was assembled on the scientific airlock and wardroom window, the astronaut-observer pointed the tracking telescope forward along the spacecraft ground track and searched for a suitable target. Tracking was commenced on the chosen target several seconds before the scheduled time to allow attainment of the tracking tempo. Tracking was continued until the end of exposure, as indicated by the sound of the camera drive mechanism. With short exposures, the observer positioned the tracking carriage initially so that two UV exposures could be made on the same target. The first exposure was initiated automatically and after its termination, the observer quickly interchanged filters while still tracking and then initiated manually the second UV exposure just after nadir as indicated by operation of the color camera. The result of this procedure was three exposures on the same site with essentially the same lighting.

Analysis of Performance

A listing of the ozone photography scheduled and performed is given in Table IV. The data digitized are indicated by asterisks beside the dates of performance.

The S063 filter pass band was chosen so that small changes in ozone concentration at the lower levels would lead to maximum changes in film density. The filters flown on SL-3 and SL-4 met experiment requirements well enough, but the short wavelength filter used on SL-4 and returned to earth was found to have deteriorated. When this filter

Table IV

OZONE - OPERATIONAL CHRONOLOGY & DATA LISTING

DATE	MD	DOY	GMT	to GMT	TRACK	REV.	MODE	CASS.	(UV)		CASS.	(Visible)		REMARKS
SL-3														
08-09-73	13	221	1344	1409	47	1255	Z-LV	BV-13	16	17	CX-12	14	16	No pairs of exposures on same site
09-03-73	38	246	1522	1538	54/55	1616/7	Z-LV	BV-15	11	14	CX-30	10	0	No pairs-no visible pix (camera malfunction)
09-06-73	* 41	249	1154	1158	25	1658	SI	BV-15	4	4	CX-29	2	4	No pairs
	41	249	1324	1348	26	1659	SI	BV-16	13	11	CX-29	11	11	1 Pair
09-07-73	* 42	250	1902	1907	43	1676	SI	BV-16	6	6	CX-29	6	6	No pairs-aircraft over San Francisco
09-08-73	43	251	2130	2144	59	1692	SI	BV-16	7	7	CX-31	6	7	No pairs-no visible pix Aircraft over Gulf of Mexico
09-14-73	49	257	1716	1725	1/2	1776/7	SI	BV-16	7	5	CX-33	4	4	2 pairs
							SL-3 Totals		64	64		53	48	
SL-4														
12-31-73	* 46	365	0058	0107	46	3340/1	SI	BV-22	10	11	CX-37	7	8	3 pairs *(All SL-4 black and white frames out-of-focus)
01-01-74	47	001	1313	1346	54	3349	Z-LV	BV-22	23	24	CX-38	21	22	No pairs
01-03-74	49	003	1034	1048	10	3376	Z-LV	BV-26	10	10	CX-38	10	10	No pairs
	49	003	1150	1210	11	3377	Z-LV	BV-26	14	15	CX-39	14	15	No pairs
01-25-74	* 71	025	1716	1733	47	3697/8	Z-LV	BV-49	14	22	CX-43	14	10	8 pairs
01-31-74	* 77	031	1451	1509	61	3783	Z-LV	BV-50	22	36	CX-49	17	19	17 pairs
	77	031	1611	1631	62	3784	Z-LV	BV-42	28	34	CX-49	18	21	All 34 B&W frames blank-(no exposures)
							SL-4 Totals		121	152		101	105	
							SL-3 Totals		64	64		53	48	
							GRAND TOTALS		185	216		154	153	

* Some or all frames digitized

was measured after flight, the degree of blocking at longer wavelengths was found to have decreased to the extent that the film density arising from the long wavelength leak of solar radiation would have masked any small changes in density that may have been caused by changes in ozone concentration. Whether this was true for the SL-3 filter is not known because the filter was not returned, but construction of the filters was presumably identical.

The S063 ozone experiment required a number of trilogies of photographs in which two ultraviolet exposures through different filters and one color exposure were made above the same ground site. Only one such group was made on SL-3, whereas 29 trilogies were obtained on SL-4. A number of frames were exposed on SL-3 during two overflights of high altitude aircraft paths. The aim was to obtain data in the ozone band that might have a bearing on the alleged destruction of ozone by supersonic transport (SST) exhausts. All of the above photographs were digitized by microdensitometering the 35-mm flight film.

It was expected that the SL-3 passes over the flight path of high altitude jet planes would show some evidence of the contrails. No traces at all were found of the contrails on any of the photographs, ultraviolet or visible color. This was surprising, for the timing of the events was such that the Skylab passed over each plane flight path within several minutes of the plane's passage. Contrails were sighted and even photographed from the spacecraft at other times; so the conclusion here is either that (a) there were no significant contrails detectable with ultraviolet light or (b) somehow the camera

field-of-view didn't include the right air space at the right time. It is possible that either or both hypotheses could be correct.

The results of the S063 ozone experiment were inconclusive. The inadequate exposures of SL-3 and the de-focused images of SL-4 did not furnish data sufficient to confirm or disprove the objectives of the experiment. Simultaneous exposures just within and just outside the ozone absorption band of the same site should show, at least qualitatively, evidence of an ozone layer.

Digitized Data

Of the 29 reels of magnetic tape containing digitized ozone data, only 2 reels are deposited with the NSSDC. The remainder are available at the Naval Research Laboratory. The 2 reels contain 2 ozone trilogies that best exemplify the experiment objective, although the photographs were out of focus, as shown in Fig. 1. Features common to all three frames of the trilogy are easily discernible as is the excessive amount of vignetting resulting from the film floating away from the focal plane.

Four precisely located v-shaped notches were cut in the framing piece of each S063 Nikon camera, so that the intersection of the lines joining opposite pairs of notches fell at the center of the optical system. These fiducial marks were used to match up the three photographs precisely and to determine where the camera was pointing. Scanning of each frame was started at the tip of the "heads" end notch and covered the other three notches. As the notches are precisely located, the scan lines that pass through them can be located readily. Matching the scans of the UV frames line for line will provide accuracy of frame match commensurate with that of tracking.

The procedure was to convert the data to intensity values, adjust for filter transmittance, solar spectral radiance and exposure time and then subtract pixel by pixel the data of the long wavelength (3200) filter from that of the short wavelength (2700) filter. The remainder would be a relative measure of the ozone. The vignetting of the field and the variance of filter transmittance with field angle were common to both UV exposures of a trilogy and could be ignored.

The digitized data are identified in Table V below. Each frame was scanned with a 25 micron square aperture, with 25 micron steps along the scan line and 25 microns between lines. Exposure information is contained in Table VI.

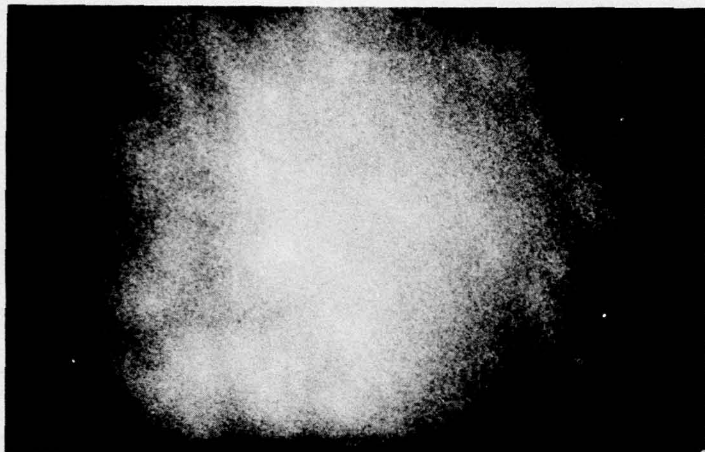
TABLE V. OZONE DIGITAL DATA

File No.	MT	File	Date	Frame No.	Pts/Rec	Recs	Slit	Rate	Filter	Exp
1	08	F1	2-26	Ref Wedge	256 x	24	25SQ	S128		
2	"	F2	"	4-173-5802	1024 x	1464	"	S255	2700	2 sec
3	"	F3	"	" 5803	"	"	"	"	3200	1 "
4	"	F4	"	4-205-7907	"	"	"	"	*	
1	10	F1	2-26	Ref Wedge	256 x	64	25SQ	S128		
2	"	F2	"	4-173-5806	1024 x	1464	25SQ	S255	2700	8 sec
3	"	F3	"	" 5807	"	"	"	"	3200	2 sec
4	"	F4	"	4-205-7909	"		"	"	*	

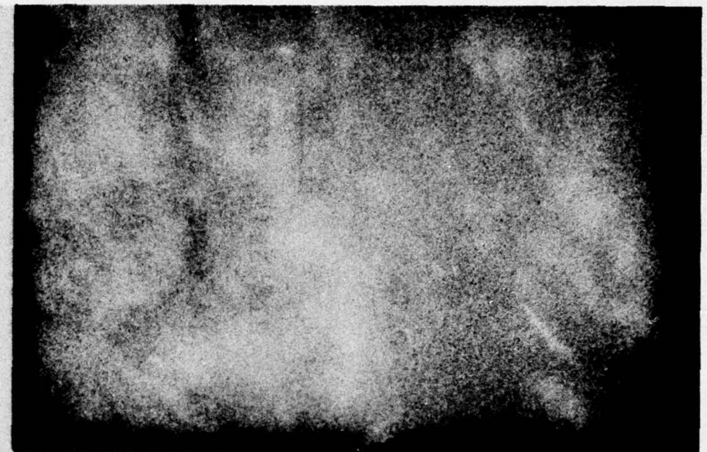
*Black and white film copy of color film

TABLE VI OZONE EXPOSURE DATA

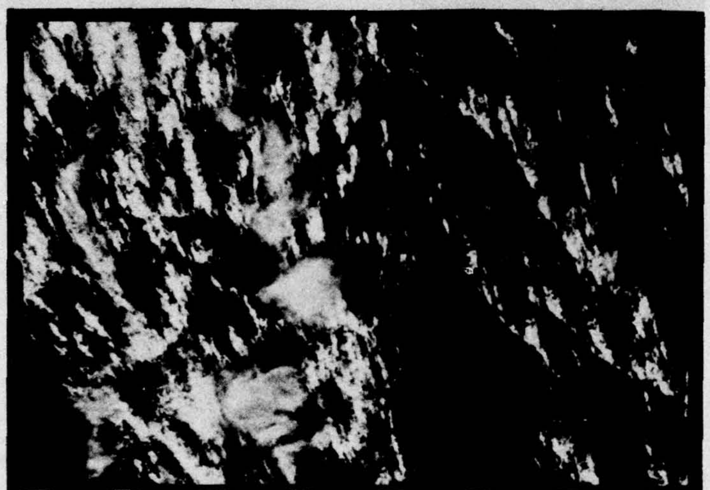
	MT 8	MT 10
Location:	15° 55'S, 25° 11'W	21° 38'S, 20° 10'W
Time:	1455GMT, 31 Jan 1974	1457GMT, 31 Jan 1974
Beta Angle:	-12.16 deg	12.16 deg
Solar Elevation:	75.33 "	69.86 "
Solar Azimuth:	137.81 "	136.31 "



FILTER
2700 Å



FILTER
3200 Å



FILTER - VISIBLE

AN OZONE TRILOGY - SL 4

Fig. 1 — An ozone trilogy — Sl 4

PART III

Auroral Photography

Objective

Photography of auroras in profile from above the lower atmosphere was one of several objectives pursued by Experiment S063 in its study of the earth's upper atmosphere. The returned pictures show vertical cross-sections of auroras with the spatial distributions of emission from the several atmospheric molecular and atomic species delineated by color. Auroral excitation is known to be caused by the influx into the upper terrestrial atmosphere of particles ejected from the sun during flares and other active events. However, occurrence of flares and auroras could not be predicted far enough in advance for Skylab scheduling, and photography of auroras was treated as a "target of opportunity."

Circumstances for an "opportunity" began to form at 1140 U.T. on September 7, 1973, with the commencement of a spectacular solar flare. The Skylab astronauts started coverage with the ATM solar instruments, and unmanned spacecraft monitored the tremendous burst of X-ray flux emanating from the violent solar eruption. About 2 1/2 days later, particles presumably ejected from the sun during the flare began arriving at the earth's upper atmosphere, as indicated by an increase in cosmic ray absorption and rapid rises in geomagnetic activity indices. By great good fortune, the Skylab orbit was oriented so that the southern auroral zone was visible during the dark portion of a number of revolutions each day. The Science Pilot, Owen K. Garriott, was able to photograph, with a hand-held camera, some of the intense auroras resulting from the earlier solar activity.

Experimental

The camera was a manually operated version of the S063 35-mm Nikon F/2 SLR electric-drive design. A 55-mm EFL lens was used at F/1.2 with 1- to 4-second exposures on High Speed Ektachrome film (SO168) developed to a speed of ASA-320. The exposures were made by darkening the compartment (the "structural transition section" of the spacecraft) in which four windows were located, allowing the best view to be selected. The crewman first wedged himself between equipment boxes for body stability and then placed one edge of the camera lens against the window pane to further stabilize the camera. Only a modest amount of star image motion resulting from camera movement was apparent in the photographs although a small amount of additional blurring of the earth scene was produced by spacecraft motion. The spacecraft attitude was held inertially fixed by automatic control of large momentum wheels. For the most part of the night the spacecraft was in the solar-oriented mode.

It was not possible for the astronaut-observer to record the exact time when each exposure was made, and as the spacecraft was moving at 4 geocentric degrees per minute of time, his location at the time of exposure was therefore not precise. When identifiable stars were available, the position of the earth horizon in the star field was used to determine the geographic coordinates of the horizon mid-point and to refine the position of the spacecraft along its known ground track. Position accuracy to several degrees in latitude and longitude was thereby possible to attain.

Results

There were 85 color photographs of auroras taken on SL-3, and on SL-4 seven black and white and four color. About two-thirds of the photos were usable, mainly because of the steady hand that held the camera. They were mostly of the activity in the southern auroral zone that resulted from the large solar flare on Sept 7, 1973.

Most of the many auroral forms--arcs, bands, rays, etc., were photographed. In a number of frames, one, and sometimes two, layers of low-level luminance are present. They are quite thin--an apparent thickness of 6 to 8 km--and have the appearance of airglow layers seen "edge-on". An estimate of their altitudes is 100 km and 120 km.

Analysis and Interpretation

The lower of the two layers was present in all auroral photographs, generally appearing reddish, but in some few instances intensifying into whitish. It is well known that color film tends to render low intensity levels reddish regardless of true color. However, the layer retained the red tinge even as it brightened with increased auroral activity. The brightness of this layer was compared with that of the rear side of an ATM solar panel illuminated at nearly normal incidence by the full moon. A value of 3.6 kilorayleighs was obtained for the zenith brightness of the layer assuming a zenith-to-horizon enhancement of 30. The solar panel reflectance was taken as 50% which may be a factor of 2 high. Considering the many uncertain values involved in the calculation, the computed layer brightness strongly suggests

that the emission is airglow. This is consistent with the measured altitude of 95-100 km and the fact that the color of the integrated emission, as sensed by the color film, would be reddish, inasmuch as the color temperature of the airglow can be approximated by a 2360°K source.

The second of the two layers of auroral activity photographed "edge-on" was always whitish in appearance, and when present, occurred about 20 km higher than the red layer just described. In many cases the bottom of this layer formed the lower boundary of clouds of activity generally described as homogeneous bands. The color of the photographic images came mostly from the green line (λ5577 Å) of atomic oxygen and from the blue-violet of the First Negative band of N_2^+, the radiations excited by low-energy electrons which are the most prevalent of the incoming particles.

Some prints of the auroral pictures in black and white are enclosed to illustrate the variety of forms photographed. The location of the spacecraft when the exposure was made is given in geographic coordinates. The midpoint of the auroral horizon was determined using the photographed starfield and spacecraft position, assuming that the line-of-sight was tangent to a layer at the 100-km level. For the the spacecraft altitude of 450 km, the point of tangency was 2160 km from the spacecraft position at a dip angle of 18.42 deg. Latitude coordinates for this point refer to the geomagnetic pole located at 78°.5S, 111°E (geographic) and longitudes are bearings measured eastward from the meridian containing the south geographic and geomagnetic poles. Time is given in local geomagnetic mean time (LGMT).

Figure 2 shows an exposure made on September 9, two and one half days after a giant solar flare, (type X-1) began at 1140 UT on September 7, 1973. The magnetic K_p index was high at 8and the auroral emissions were intense, with the red 6300-6364 Å glow especially prominent. On the other hand Figure 3, a photograph taken 3 days later, shows prominent discrete auroras when the K_p index was down to about 2. Figure 4 is interesting for two reasons: (a) because of the discrete auroral arc streaming across the field-of-view and (b) because of the sharp line of emission extending at a uniform altitude above the earth horizon. The green auroral arc follows generally along geomagnetic latitude lines with its brightest portion over 350 km in length. The line of emission is an "edge-on" view of a thin layer that covers a considerable area at constant altitude.

Figure 5 shows the entire bright green arc of which the left end is also shown in Figure 4. The arc extends over 400 km and then folds toward the observer at both ends. At the right is an edge-on view of a whitish-appearing layer (probably the green line at 5577 Å) that is about 20 km above the one of Figure 4. The exposure is much shorter than that of Figure 4, and the lower layer does *not* show in the reproduction as it does faintly to the left on the original film. Figure 6 shows a green arc extending out from a diffuse layer and curving around into an S-shaped form, assuming the lower border to be at a reasonably constant altitude, as is the case with the majority of auroral forms.

Figure 7 is an early dawn view of two luminous layers, seen separately in Figures 4 and 5, with no discrete auroral forms present. The lower

layer is quite faint in the reproduction, but it was distinct and reddish in the original film.

Figure 3 includes simultaneously all of the various features of the auroral photographs. A lower layer is distinct with discrete auroras on the horizon blending in with a homogeneous arc, and a diffuse upper layer is capped by the oxygen red emission extending upward several hundred kilometers. Visually, the darkness of the space between the two emitting layers is enhanced by the contiguous bright layers. The intensity of the upper layer does decrease with decreasing altitude below the maximum quite rapidly. This would tend to indicate that the bright shell of luminosity is of limited extent, as might be expected for a diffuse layer of precipitating particle excitation.

Apparent altitude vs. relative intensity curves are shown in Figures 8-10. A line segment beside the curve at zero apparent altitude is the assumed position of the apparent earth horizon. This was difficult to place because the horizon was indistinct and further confused by clouds. The altitudes are apparent because they are referred to the visual horizon. The effect of the atmospheric refraction and cloud cover adds 12-13 km to the apparent altitude of the emitting layers.

Digitized Data

Seven reels of magnetic tape bearing auroral data are deposited with the NSSDC: tape 58, parts A, B, and C; tape 61, parts A and B; and parts A and B of tape 67. The 37 auroral frames that were digitized are included in Table VII, which lists magnetic tape and file number, scanning aperture, size of step (ΔX) in a scan line and separation (ΔY) of the scan lines in micrometers. Data deposited with the NSSDC are denoted by an asterisk (*) and are listed according to magnetic tape file number and label in Table VIII. RGB scans were made through red, green, and blue filters.

The microdensitometer scanned across the earth horizon and the emitting layers with a 10 x 200 micrometer slit placed with long dimension parallel to a line connecting the farthest separated distinct ends of one of the layers or the earth horizon, whichever appeared best. This chord served as the baseline to allow for the curve of the horizons when comparing the altitude of a layer at one position on the photograph with that at any other position in order to derive an average value for layer altitude. The scanning slit was moved in steps of 4 micrometers along a scan line and 80 micrometers between scan lines. This gave ample data for averaging out the grain noise of the photographs. Densitometry of the calibration step wedges on the auroral film is recorded on tape 61, file 5. It should be noted that the reference wedge was scanned at the beginning and/or end of each scan session, and is identified by date on the tape label. In general, the REF WEDGE of the same date as a frame of interest and closest in file number to a desired file should be selected for use in standardizing data.

Tape 67 was used to record scans made with red, green and blue tricolor filters on color copies of frame numbers 3145 and 3151 and of the color calibration wedge. From these data color separation negatives can be prepared and used to reconstruct the auroral scenes in their true colors.

In addition to the auroral data, tape 61 includes similar microdensitometer scans of the lower atmosphere in files 9 through 17. These exposures were made by E. G. Gibson, the Science Pilot on SL-4, who used a 300-mm focal length lens on the Nikon camera. They cover the period before twilight and past sunrise. The 14-frame sequence is listed in Table IX, with an asterisk identifying the files on tape 61, deposited at NSSDC.

Table VII. Complete Listing of Digitized Auroral Data

Frame Number		Tape #	File #	Aperture		X	Y	Filter
SL3-130	3096	49	F2	25	square	25	25	
	3097	49	F4		"	"	"	
	3098	49	F5		"	"	"	
	3099	49	F6, 10		"	"	"	
	"	49	F12		"	10	10	
	"	59	F2, 3, 4		"	25	25	RGB
	3100	49	F7	50	"	50	50	
	3103	49	F14	25	"	25	25	
	"	64	F2, 3, 4		"	"	"	RGB
	3104	49	F15		"	"	"	
	3106	49	F16		"	"	"	
	3107	50	F2	50	"	50	50	
	"	64	F5, 6, 7	25	"	25	25	RGB
	3108	50	F3	50	"	50	50	
	3109	50	F4	50	"	50	50	
	3110	50	F5	50	"	50	50	
	"	65	F5, 6, 7	25	"	25	25	RGB
	3111	50	F6	50	"	50	50	
	3112	50	F7		"	"	"	
	3113	50	F8	25	"	25	25	
	"	57	F2, 3	10x200		4	80	
	3114	50	F9	25	square	25	25	
	3115	50	F10		"	"		

Table VII (Continued)

Frame Number	Tape #	File #	Aperture	X	Y	Filter
SL3-130-3116	50	F11	"	"	"	
3120	63	F3	25 square	25	25	
3121	63	F4	"	"	"	
3122	63	F5	50 square	50	50	
3123	63	F6	"	"	"	
3124	63	F7	"	"	"	
"	57	F5	10x200	4	80	
3125	63	F8	50 square	50	50	
3126	57	F6	10x200	4	80	
"	* 58	F9, 10, 11, 12, 13	"	4	80	
"	63	F9	50 square	50	50	
3130	57	F7	10x200	4	80	
"	60	F6, 7, 8	"	"	"	
"	63	F 10	50 square	50	50	
"	65	F5, 6, 7	25 square	25	25	RGB
3131	57	F8	10x200	4	80	
"	63	F 11	50 square	50	50	
"	66	F2, 3, 4	25 "	25	25	RGB
3132	57	F9	10x200	4	80	
"	60	F1, 2, 3, 4, 5	"	"	"	
3135	63	F12	50 square	50	50	
3136	63	F13	"	"	"	
3140	* 58	F1, 2, 3, 4, 5, 6	10x200	4	80	

Table VII. (Continued)

Frame Number	Tape #	File #	Aperture	X	Y	Remarks
SL-130-3140	66	F5,6,7	25 square	25	25	RGB
3141	57	F10	10x200	4	80	
3144	* 61	F1	"	"	"	
3145	48	F18	50 square	50	50	
"	60	F9,10, 11	10x200	4	80	
"	* 67	F2,3,4	25 square	25	25	RGB
3146	* 61	F2	10x200	4	80	
3149	48	F19	50 square	50	50	
3151	48	F20	"	"	"	
"	* 61	F3	10x200	4	80	
"	* 67	F5,6,7	25 square	25	25	RGB

* Magnetic tape filed with NSSDC

TABLE VIII. DIGITIZED AURORAL DATA DEPOSITED AT NSSDC

MT	File	Date	Subject	Frame	No. Pts./Rec.	Recs	Slit	Rate
+58	F1-6	3-13	A	130-3140	2500 x	350	10 x 200	64
"	F 07	3-13	REF WEDGE		100 x	24	10 x 200	S128
"	F 08	3-14	" "		100 x	24	10 x 200	"
+"	F9,10,11,12,13		A	3126	2500 x	324	10 x 200	S 64
61	F 01	3-14	ASL	3144	2500 x	376	10 x 200	S 64
x"	F 02	"	"	3146	"	"	" "	"
"	F 03	"	"	3151	2500 x	450	" "	"
"	F 04	"	REF WEDGE		100 x	24	" "	S128
"	F 05	3-15	CALWEG	130	236 x	72	" "	"
"	F 06	3-15	CALWEG		752 x	72	25SQ	"
"	F 07	3-15	REF WEDGE		320 x	24	25SQ	"
"	F 08	3-15	CALWEG 4-200		236 x	72	10 x 200	128
"	F 09	3-15	ASL	200-7648	1536 x	450	10 x 200	S 64
"	F 10	"	"	7647	"	"	" "	"
"	F 11	"	"	7646	"	"	" "	"
"	F 12	"	"	7645	"	"	" "	"
"	F 13	"	"	7644	"	"	" "	"
"	F 14	"	"	7643	"	"	" "	"
"	F 15	"	"	7642	"	"	" "	"
"	F 16	"	"	7648	"	"	" "	"
"	F 17	"	"	7655	"	"	" "	"

+ (files 1 through 6 and 9 through 13 on tape 58 have the same I.D. heading)

x The MT label for 61F02 wrongly lists the frame as ASL4146

TABLE VIII. Continued

MT	File	Date	Subject	Frame	No Pts/Rec	Recs	Slit	Rate
67	F 01	4-3-5	REF WEDGE		320 x	24	25SQ	S255
"	F 02	4-4-5	AUBLU-3145		1440 x	960	25SQ	"
"	F 03	"	AUGRN-3145		"	"	"	"
"	F 04	"	AURED-3145		"	"	"	"
"	F 05	"	AUBLU-3151		"	"	"	"
"	F 06	"	AUGRN-3151		"	"	"	"
"	F 07	"	AURED-3151		"	"	"	"
"	F 08	4-4-5	CALBLU-130		768 x	72	"	"
"	F 09	"	CALGRN-130		"	"	"	"
"	F 10	"	CALRED-130		"	"	"	"

Table IX. Digitized Photographs of the Lower Atmosphere

Frame Number		Tape #	File #	Aperture	X	Y	Filter
SL4-200	7639	69	F8	10x200	4	80	
	7640	"	F7	"	"	"	
	7641	"	F6	"	"	"	
	7642	61	F15	"	"	"	
	7643	"	F 4	"	"	"	
	7644	"	F 3	"	"	"	
	7645	"	F 2	"	"	"	
	7646	"	F11	"	"	"	
	"	68	F2, 3, 4	25 square	25	25	RGB
	7647	61	F10	10x200	4	80	
	"	68	F5, 6, 7	25 square	25	25	RGB
	7648	61	F9, 16	10x200	4	80	
	7650	69	F5	"	"	"	
	7651	"	F4	"	"	"	
	7652	"	F3	"	"	"	
	7655	61	F17	"	"	"	

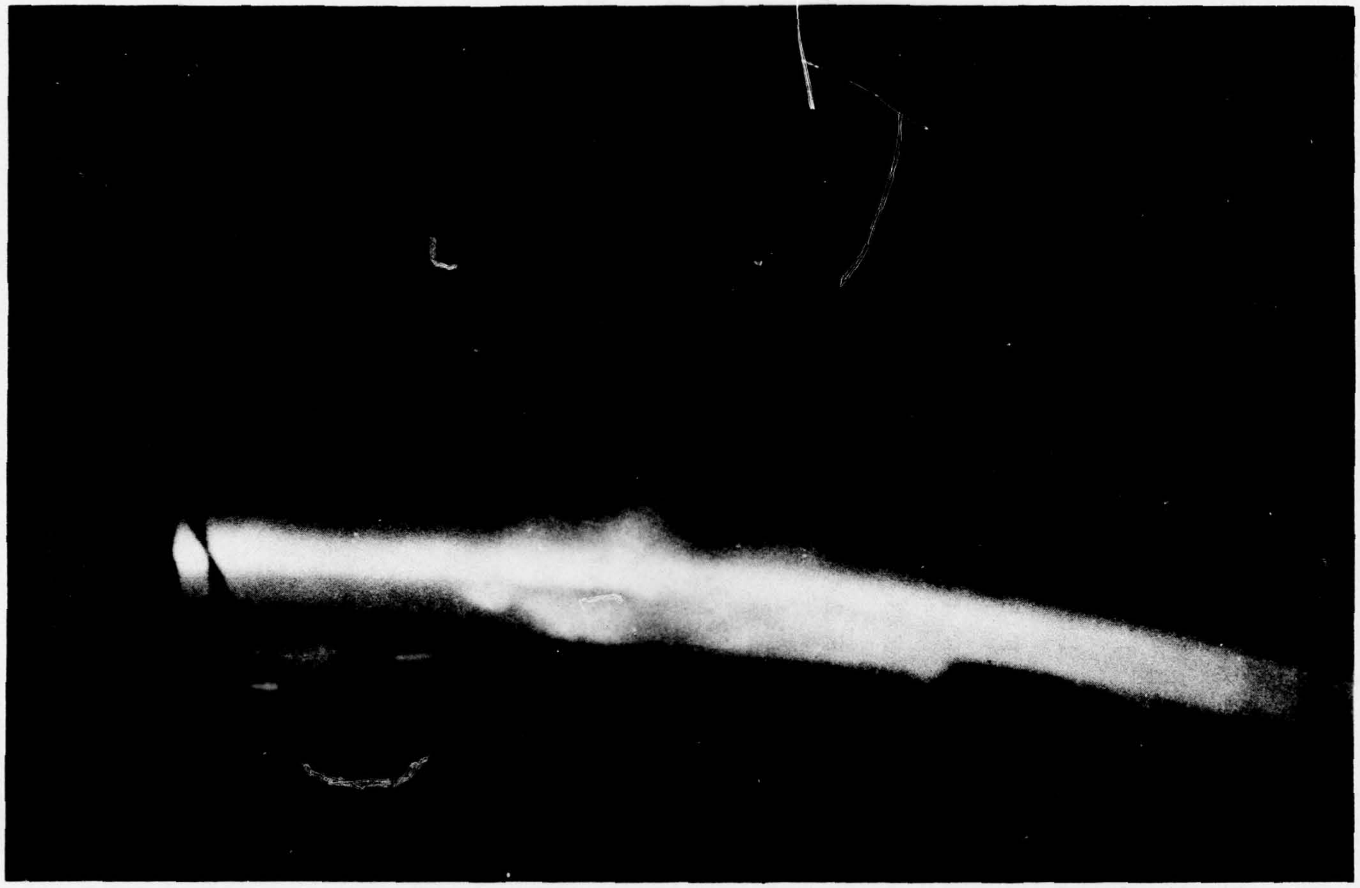


Fig. 2 — Sept. 9, 1973, at 2140 UT from spacecraft position 42°.4S - 62°.4E. Auroral horizon midpoint at 67°S - 97°, 2322 hrs LGMT. Very intense green emission from the particle-excited atomic oxygen line at 5577 Å extends in a band parallel to the earth horizon, with some discrete auroral forms also present. Emission from atomic oxygen at 6300-6364 Å is also prominent as a red glow extending upward from the green band to beyond 250 km. Rays above the main layer parallel the geomagnetic lines of force. The bright star near mid-photo is θ Centauri. The structure at left is part of an ATM solar panel with its antisolar side illuminated by the full moon. Frame 3107.

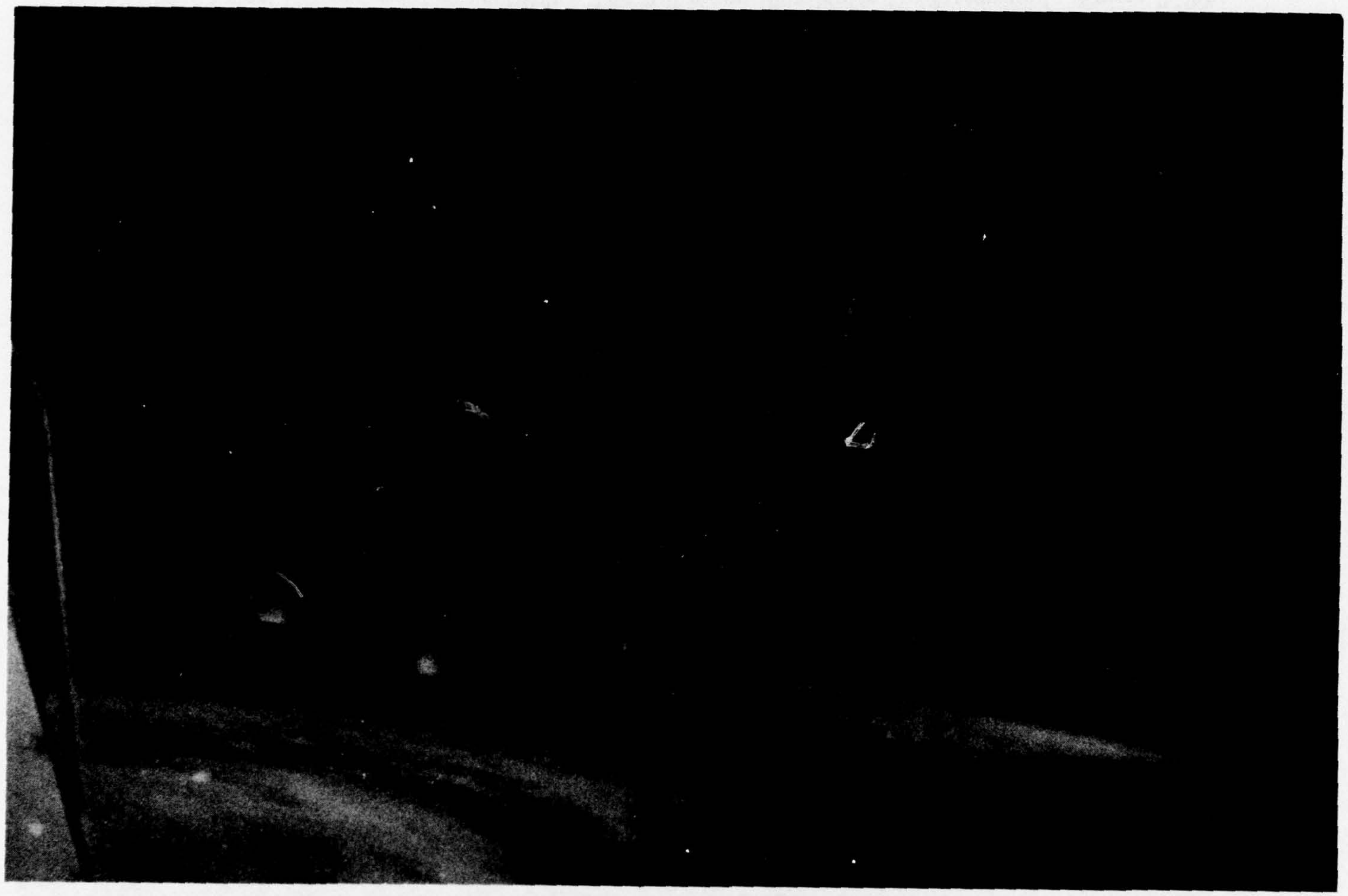


Fig. 3 — Sept. 12, 1973, at 1759 UT, from 42°.9S - 101°.6E. Auroral horizon midpoint at 70°S - 137°, 2236 hrs LGMT. Discrete auroral forms along with diffuse bands, two luminous layers and a red auroral glow above. The Earth is illuminated by the full moon and reflected auroral light. The brightest star is θ Centauri. Frame 3145.

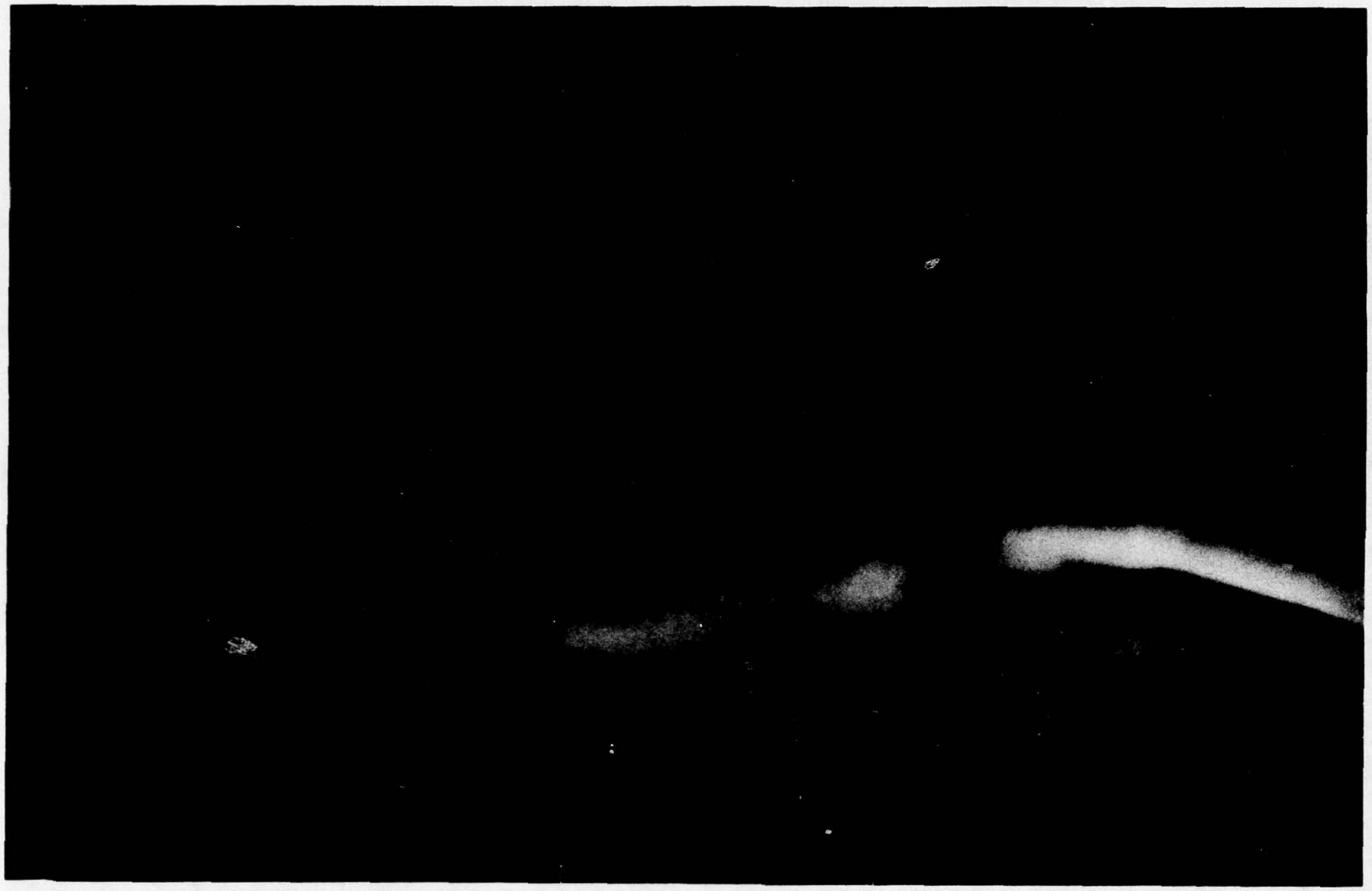


Fig. 4 — Sept. 11, 1973, at 1843 UT from 45°.6S - 104°E. Midpoint auroral horizon at 74°S - 140°, 2326 hrs LGMT. A spectacular discrete rayed arc appears at right, with a thin shell of quiet luminescence viewed "edge-on" at left. The sharp upper edge of this band has the character of airglow, but the overall intensity appears to be excessive, and probably includes radiation induced by particle bombardment. σ Hydrae and π Librae are the bright stars left and right respectively. The full moon illuminates the foreground. Frame 3130.

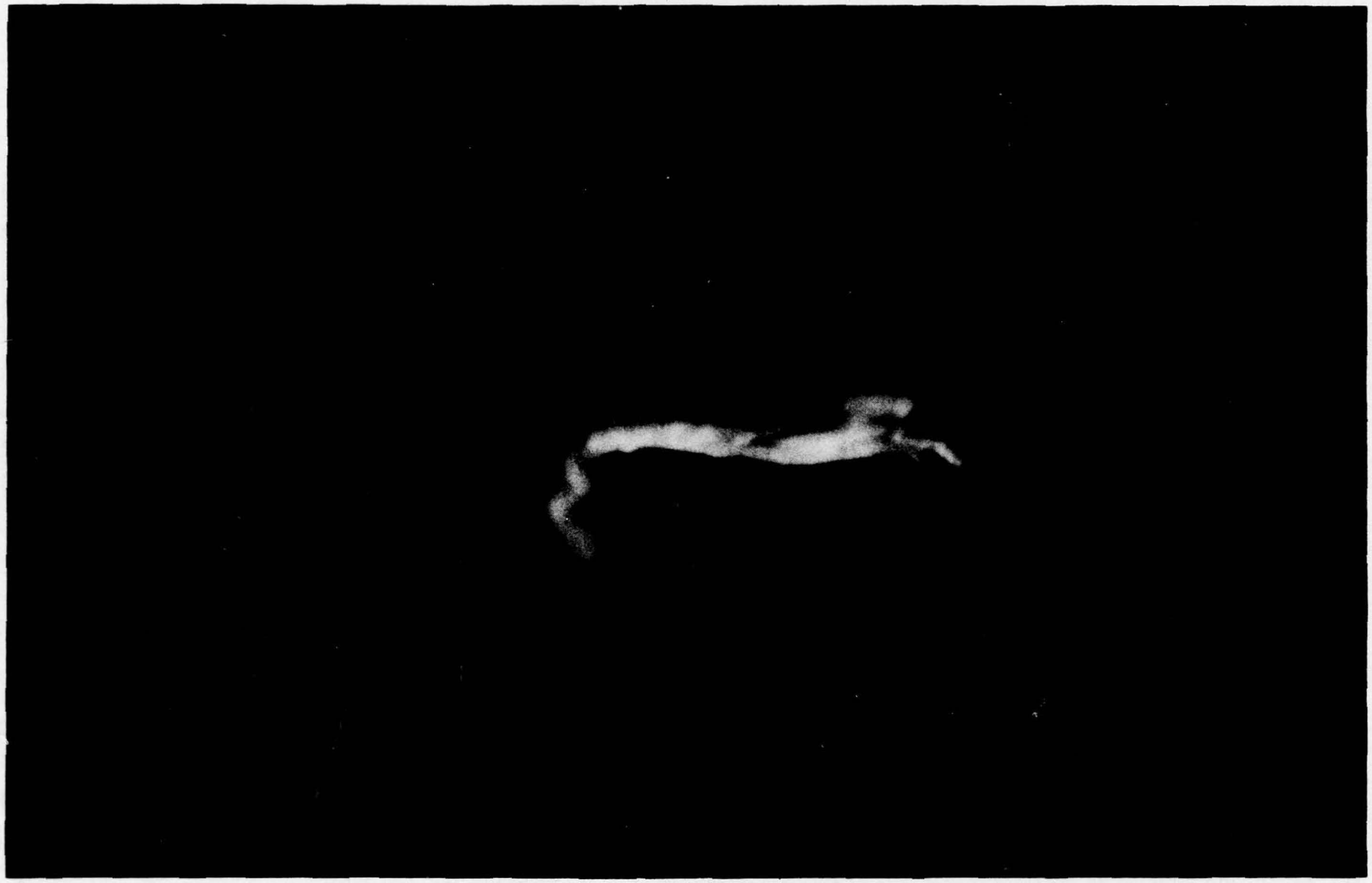


Fig. 5 — Sept. 11, 1973, at 1844 UT, from 47°.7S - 111°.5E. Auroral horizon midpoint at 71°S - 142°, 2337 hrs LGMT. The complete rayed arc, shown in part in Fig. 4 is seen to extend over 400 km in length, trailing off toward the observer at both ends. The lower border at 120 km is coincident with that of the luminous layer seen edge-on at the right. Unseen on the print, but visible in the original is another band extending to the left and 20 km lower in altitude. This lower band is at the same altitude as the luminous layer seen in Fig. 2. Antares, α Scorpii, is the bright star at the top of picture. Frame 3131.

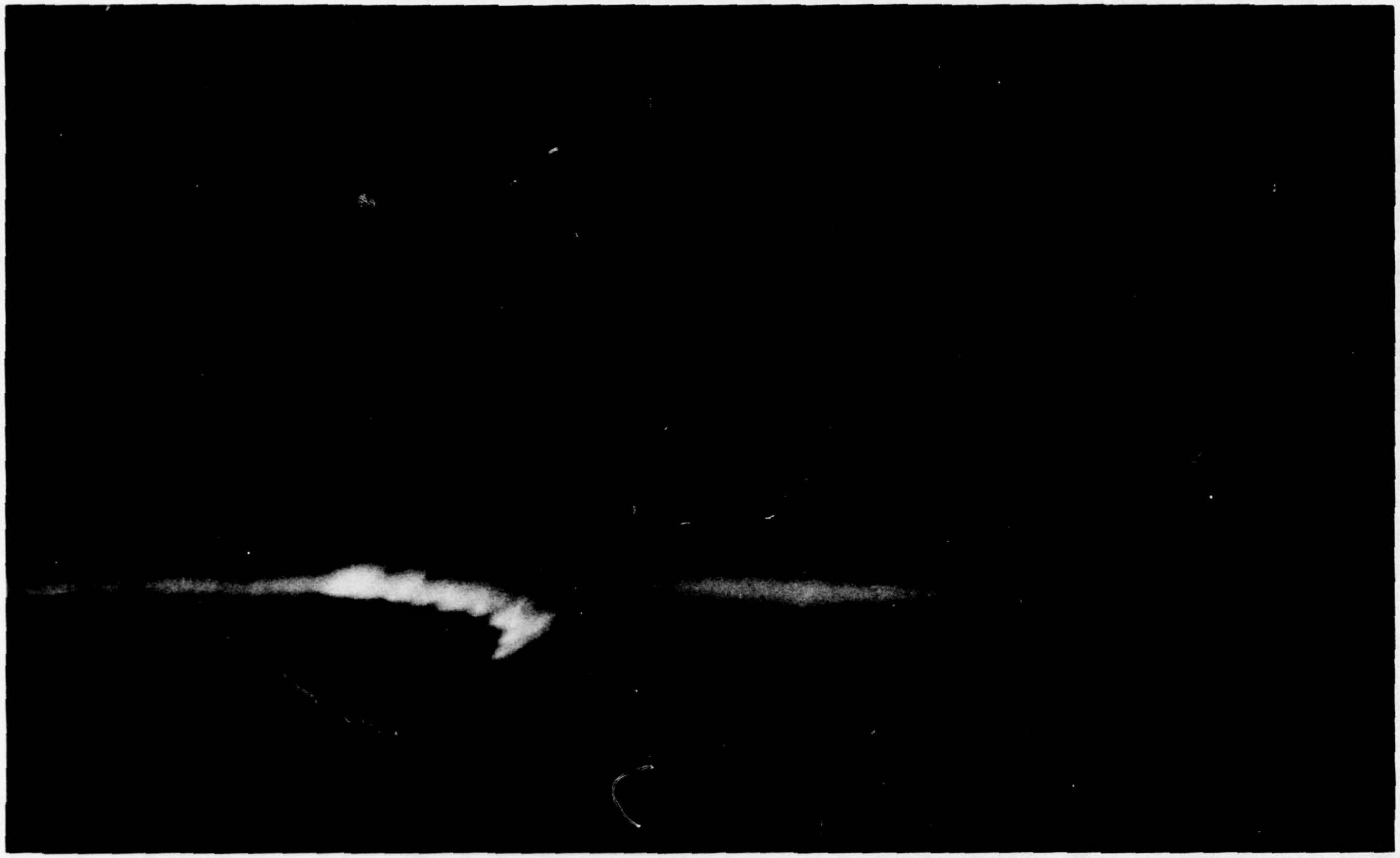


Fig. 6 — Sept. 11, 1973, at 2152 UT, from 48°.6S - 68°.8E. Auroral horizon midpoint at 71°.5S - 95°, 0029 hrs LGMT. An intense green rayed arc that folds back upon itself and blends in with a less bright homogeneous band extending toward the horizon as a thin layer. Antares, α Scorpii, is the bright star at the right. Frame 3135.

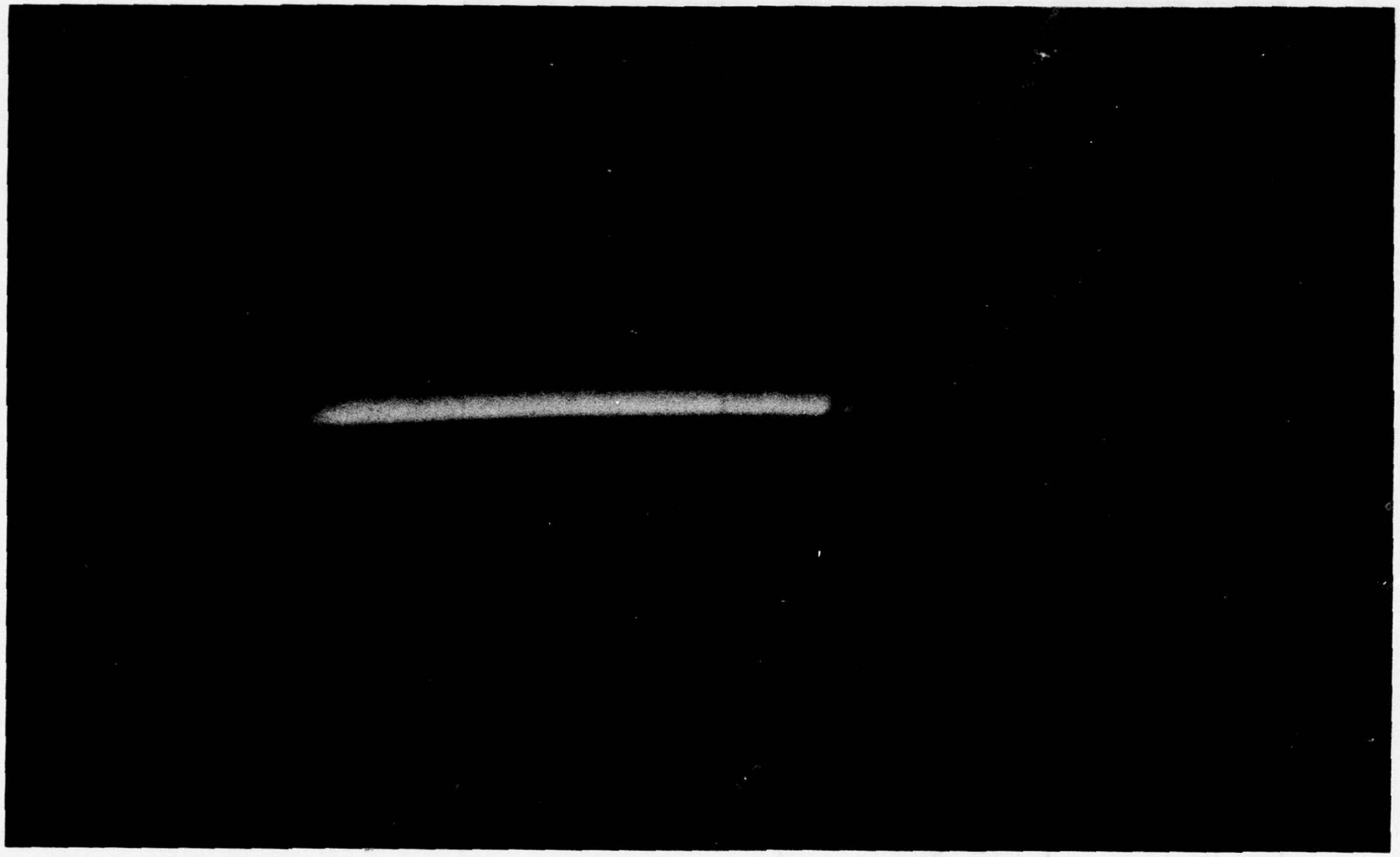


Fig. 7 — Sept. 11, 1973, at 2325 UT from 48°S - 49°E. Midpoint of auroral horizon at 68°.5S - 125°, 1320 hrs LGMT. A view at early dawn showing two distinct luminous layers above the brightly illuminated lower atmosphere. These layers are similar to the ones in Figs. 4 and 5 and are at 100 km and 120 km. No discrete auroral forms are present. The top layer is whitish, and its intensity is twice that of the lower layer, which generally appears reddish. The two bright stars above the layers are γ Hydrae at left and δ Crateris at lower right. Frame 3140.

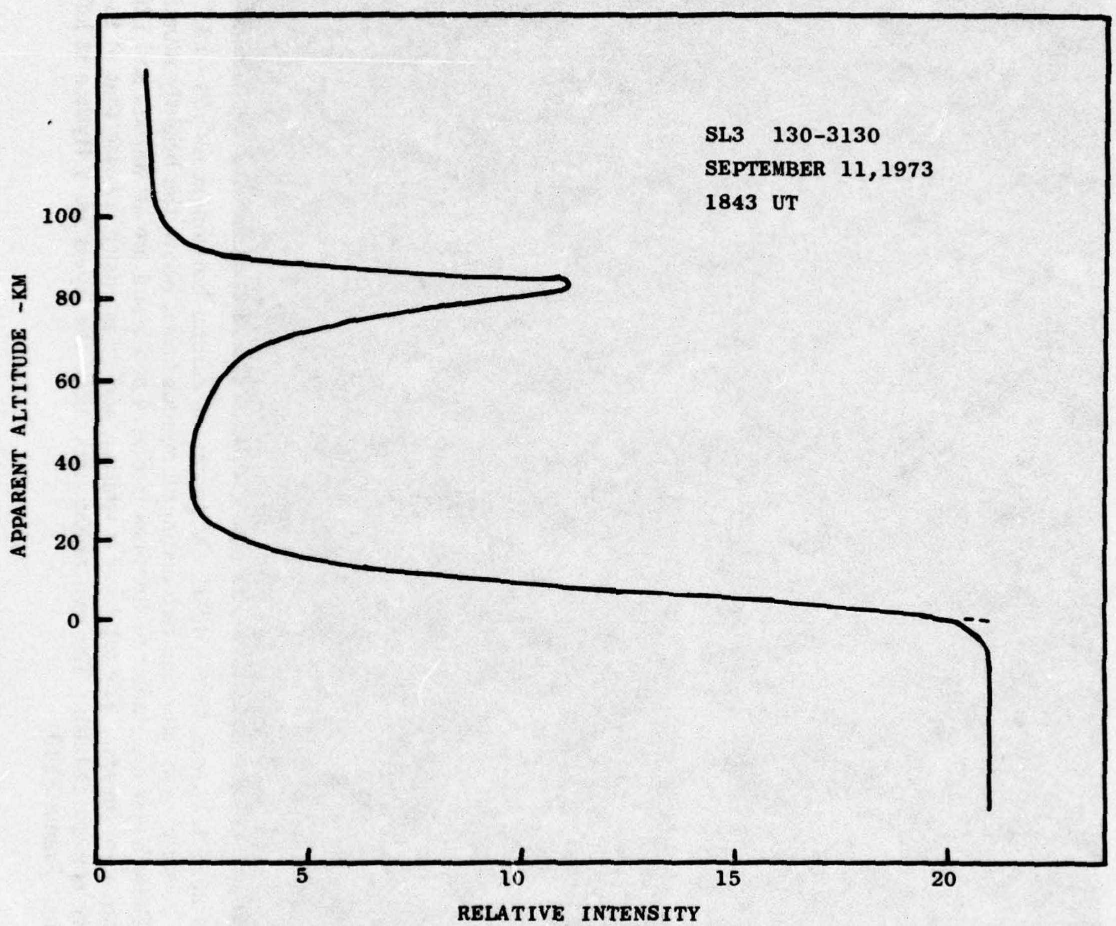


Fig. 8 — Apparent altitude of luminous layer in Fig. 4

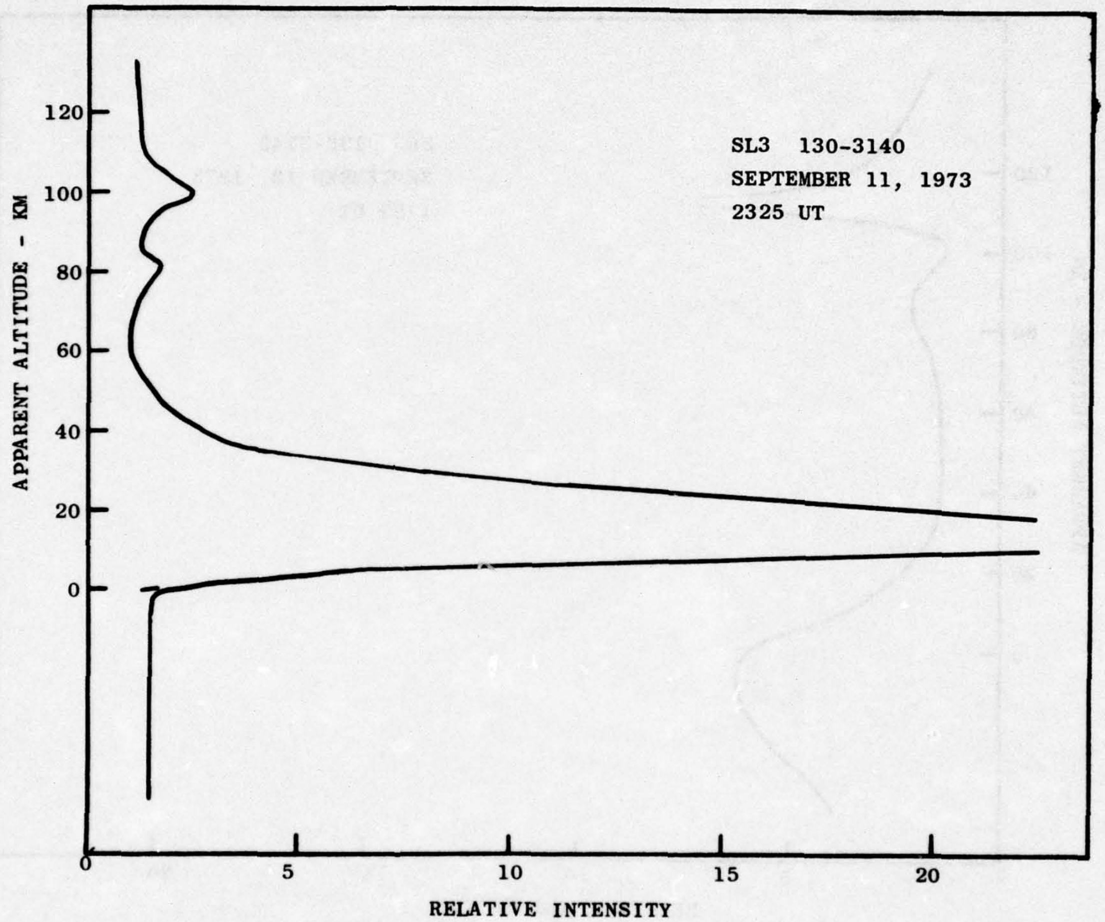


Fig. 9 — Apparent altitudes of luminous layers in Fig. 7

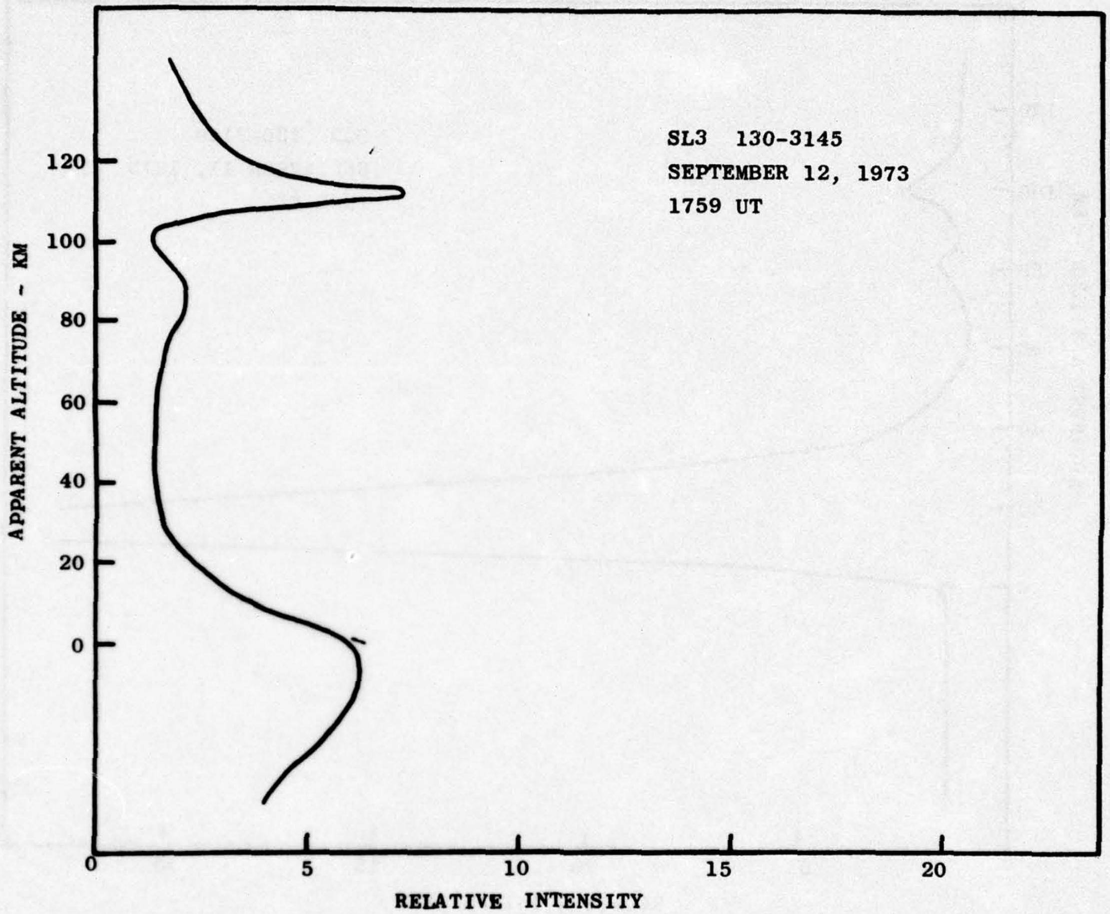


Fig. 10 — Apparent altitudes of luminous layer in Fig. 3

PART IV

Comet Kohoutek Photography

The camera and filter system of Experiment S063 was flexible and broadly useful to a wide variety of applications, among which fell the unexpected opportunity to study Comet Kohoutek from above the earth's atmosphere. A combination of this, filters borrowed from experiment T025, and the Articulated Mirror System (AMS) from experiment S019 allowed photography to be done at ultraviolet wavelengths and in the light of various atomic and molecular species relevant to cometary studies.

Objectives

The S063 Experiment objective was to obtain a time sequence of exposures of the comet as it approached and receded from the sun, in order to detect and trace the growth and decay of various atomic and molecular species, especially the OH emission at 3090 Å. Emphasis was placed on ultraviolet radiations not observable from the ground, but some filters were included to give better time-history than once-a-day availability from the ground. The filters of Experiment T025 that were used are listed in Table X. The task of T025 was to extend the coverage of the comet close to perihelion by using the occulting disk of its coronagraph to mask out the sun during extravehicular activity of the Skylab crew.

A special sequence of photos was made without filters and with a 135-mm focal length "operational" lens on December 8, 9, and 10, 1973 when the earth passed through the orbital plane of the comet. The

TABLE X. COMET KOHOUTEK FILTER IDENTIFICATION

Skylab Experiment T025 Filters Used by S063 for Comet Photography

Filter No.	Peak λ	Band Width	Use
	Ultraviolet Spectral Region		
A_1	No filter		White light photography
A_2	2530Å	124Å	Broad band
A_3	3581	290	Broad band
A_4	3361	30	NH emission
B_1	3250	60	OH background
B_2	2826	284	Broad band
C_1	3873	30	CN bands in tail
C_3	3100	60	OH emission (3090Å band)
D_2	3940	25	CN background
	Visible Spectral Region		
B_3	4430Å	100Å	Comet tail-dust
B_4	5500	200	Broad band
C_2	4700	60	C_2 emission
C_4	6000	--	Long wavelength cut-off
D_1	4262	20	CO^+ emission
D_3	4900	60	C_2 background
D_4	5890	30	Na emission

objective of these photos was to reveal any dust or particulate matter which the comet may have shed. Best observing conditions for this purpose occurred when the thin layer of material was viewed "edge-on" from the plane of the orbit. From the ground, the light scattered from such particles is hard to detect above starlight, airglow, and other extraneous light scattered from the atmosphere. Thus, Skylab presented most favorable viewing conditions for this objective.

Analysis of Performance

One of the outstanding qualities for which Comet Kohoutek became noted was its faintness compared with predicted magnitudes. The effect on S063 photography was to restrict the period of days over which adequate exposure times could be attained and the number of filters which could be used during an observing session. The length of each observing session, or the amount of time the spacecraft was in shadow when the comet was visible, was limited by the geometrical circumstances of the orbital position with respect to the sun and comet.

Exposure times were derived for S063 partly from a ground-based program established by T025 on Mount Haleakala, Hawaii, to obtain exposures of the comet using equipment identical to that aboard Skylab. Exposure data were obtained from Hawaii and were extrapolated to above the atmosphere using extinction tables derived for the site and stars identified on the comet photographs. Visual magnitude curves plotted by the Kohoutek team at the Houston control center were also used in estimating daily changes in visual brightness. A rocket flight from White Sands, New Mexico, by Opal and Carruthers of NRL using

an ultraviolet lens and 3090 Å filter similar to that employed by S063 also gave exposure data at 3090 Å.

Table XI lists the exposures actually made. In conjunction with the filtered exposures, at least one white-light exposure per observing session was made to obtain the comet position in the field-of-view. This procedure proved to be extremely valuable in post-mission analysis. In some cases only the comet and one or two stars were exposed at a particular filter wavelength, while at other wavelengths or other times, stars but no comet were detectable. On one of the longest and most desirable observing sessions, this technique also unfortunately revealed that the comet was not in the field-of-view of the AMS. Subsequent to this period it was discovered that an offset pointing error of about four degrees accounted for this situation. In order for the S063 camera to view the comet, the spacecraft was rolled about the long-axis of the Workshop, or X-axis, by various degrees up to 90, and the AMS was rotated and tilted by calculated amounts. The stability of gyro-controlled pointing in this mode was generally sufficient for the exposure times available. Movement aboard the spacecraft during exposures was also minimized.

Eight observing sessions were accomplished before perihelion between December 5th and 22nd, and six sessions were completed after perihelion between January 5th and 28th. A total of 77 exposures were thus made with the AMS and spacecraft maneuvers. Between December 31st and January 8th, there were also ten sessions not requiring spacecraft maneuvers. During this time hand-held photography was done from windows in the Command Module and the

Table XI

COMET KOHOUTEK - OPERATIONAL CHRONOLOGY and DATA LISTING

DATE	MD	DOY	GMT	to GMT	REV.	MODE	CASS.	A_1	A_2	A_3	A_4	B_1	B_2	C_1	C_3	D_2	B_3	B_4	C_2	C_4	D_1	D_3	D_4
								Filters															
								(				UV				)	(		Visible				)
12-05-73	20	340	0246	0252	2967	AMS	BE-08			2		1			2								
12-08-73	23	342	1829	1836	3005	AMS	BE-08	3		(135mm lens)(all exposures out-of-focus)													
12-09-73	* 24	343	2054	2100	3021	AMS	BE-08	3		(135mm lens)													
12-10-73	* 25	344	1706	1713	3033	AMS	BE-08	3		(135mm lens)													
12-17-73	* 32	351	1659	1704	3134	AMS	BE-08	1		1		1			1								
12-21-73	* 35	354	0150	0154	3183	AMS	BE-08	1		1		1			1								
12-21-73	* 36	355	2336	2340	3196	AMS	BE-08	1						1		1			1		1	1	
12-22-73	* 37	356	1643	1646	3206	AMS	BE-08	1		1		1			1								
01-03-74	49	003	0200	0210	3370	HH	BV-26	2													1		
	49	003	1715	1719	3380	HH	BV-26	2						1					1		1	1	
01-05-74	51	005	0153	0160	3399	HH	BV-	2						1		1	1	2	1		1	1	
	51	005				HH	BV-	2						1			1	1	1		2	1	
	51	005	2337	2345	3413	AMS	BE-09	1		1		1		1	1	1							
01-06-74	52	006	1951	1955	3424	HH	BV-27	2						1					1				
	52	006	2301	2305	3426	HH	CI-112			(2 color)													
01-07-74	53	007	1406	1409	3435	HH	BV-28	2						1					1				
01-08-74	54	008	0125	0129	3442	HH	CI-113			(1 color)													
			0125	0129	3442	HH	BV-28	2						1					1				
01-08-74	54	008	2135	2143	3454	HH	CI-113			(1 color)													
			2135	2143	3454	HH	BV-28	2						1					1				
01-09-74	54	009	0041	0052	3456	AMS	BE-09	2		1	1	1		1	1	1					1		

* Data digitized

Table XI. Continued

COMET KOHOUTEK - OPERATIONAL CHRONOLOGY and DATA LISTING

DATE	MD	DOY	GMT	to GMT	REV.	MODE	CASS.	A_1	A_2	A_3	A_4	B_1	B_2	C_1	C_3	D_2	B_3	B_4	C_2	C_4	D_1	D_3	D_4
								(				UV				)(			Visible				)
01-09-74	55	009	2054	2109	3469	AMS	BE-09	2		1	1	1	1	1	1	1					1		
01-12-74	58	012	2201	2218	3513	AMS	BE-09	1		1	1	1			1		1	1	1	1		1	1
01-13-74	59	013	2124	2139	3527	AMS	BE-09	1		1	1	1		1	1	1							
01-28-74	73	028	0022	0026	3716	AMS	BE-11	1							1								
						HH		16	0	0	0	0	0	7	0	1	2	3	7	0	5	3	0
						AMS		21	0	10	4	9	1	5	11	5	1	1	2	1	3	2	1
						TOTALS		37	0	10	4	9	1	12	11	6	3	4	9	1	8	5	1

	UV	Visible	Color	No Filter
HH	8	20	4	16
AMS	45	11	0	21
TOTALS	53	31	4	37

Structural Transition Section. Forty-four exposures were accomplished with visible filters and with color film, and eight exposures with UV filters (3873Å CN Band). A report describing the S063 operation in detail was prepared by the MSFC/Kohoutek Team and is titled "Compilation of the S063 *Operational Information.*"

Results

Most of the hand-held exposures on black and white film were made with the camera which produced out-of-focus images and therefore produced nothing of value. One of the four color exposures was good; the remainder showed excessive camera motion during the four second exposures.

Although the ultraviolet exposures through the AMS were not as well exposed as desired, several showed promise of being useful. A reduction of film sensitivity from that expected was found, partly due to fogging by energetic particles during the long third mission. Development of the film also resulted in a somewhat slower speed than had been anticipated.

The 135-mm white light exposure made on December 9th showed an antitail at 246.5 degrees from the main comet tail. No other sighting for this date was reported, but the feature was observed in detail by the astronauts on December 29th and subsequently was extensively measured and photographed from the ground from January 4 through February 24.

Figure 11 shows an isophote plot of microdensitometer traces (made on the original film) of the comet and the two tails. A spacecraft perturbation of about two arc minutes caused an image doubling,

as seen dramatically from the bright star near the comet. The contours are drawn for relative density levels and are indicated by symbols on the plot. The symbol key is shown in the insert. Note that the antitail is characterized by a sharp edge, fading to a broad fan-like structure to one side. Recent work by Sekanina (references 1 and 3) applying a theory of Finson and Probstein (reference 2) to the prediction of anomalous tails indicates that the antitail may be identified with cometary synchrones, which are the locus of particles of all sizes that were ejected at the same moment from a comet's nucleus, the smaller particles having been driven farther away by solar radiation pressure. The fact that the tail extends toward the sun is an indication of the amount of time elapsed since the expulsion of the observable particles, and generally is of the order of 30 to 100 days. The older synchrones tend to "pile-up" in the direction toward the sun and result in a sharp edge with a fuzzy or fan-shaped locus of newer synchrones oriented to one side. Apparently the amount of sharpness and the pile-up to one side is also partly due to geometrical orientation as viewed from earth. Also, the observable synchrones are made up of relatively large particles (.1 mm to 1 mm). In the case of Comet Kohoutek, the observation on December 9th may indicate considerable mass loss prior to perihelion and may help explain the lack of expected brightness.

The 135-mm exposures on the 8th and 10th of December unfortunately were not good exposures and could not be used to substantiate the December 9th recording. On December 8th, the film was exposed in camera NK02 and was out-of-focus in the film plane. On December 10th

the spacecraft moved about four arc minutes during the exposure, resulting in a double image. The double images were well separated, but neither was exposed adequately to show the faint antitail.

The original film on which the Comet Kohoutek exposures were made was examined in detail using a high resolution microdensitometer (a PDS system by Perkin-Elmer Corp.). Data digitized are indicated in Table XI by an asterisk adjacent to the cassette number. The high precision of the scanning mechanism made it possible to compare the exposures taken through the several filters with those taken in white light and to identify star and comet images unequivocally. Several images made through the 3090 Å (C3) and 3581 Å (A3) filters were thus found that were not detected during previous visual examinations. In addition to the antitail reported to the MSFC Comet Kohoutek Group, there was also discovered on a white light photograph the hint of an antitail that had been overlooked previously.

Comet Kohoutek

References

1. Zdenek Sekanina, Sky and Telescope 47, 374-377, 1974.

2. Finson, M. L., and R. F. Probstein, Ap. J. 154, 327-352, 1968.

   Finson, M. L., and R. F. Probstein, Ap. J. 154, 353-380, 1968.

3. Zdenek Sekanina, NASA Semiannual Progress Report No. 5, April 1974.

4. MSFC/Kohoutek Team, Compilation of the S063 Operational Information.

DIGITIZED DATA

Comet photographs of potential interest are listed by frame number. The filter used is identified along with the magnetic tape and file numbers. Included in the latter are the file numbers for the pertinent reference wedge data recorded with the whitelight numbers.

It is intended that interested users would obtain the tapes directly from the PI at the Naval Research Laboratory, as the instructions for locating the comet and star images are too diverse and detailed to be recorded for NSSDC purposes.

Table XII. Comet Kohoutek Digitized Data

FRAME NUMBER	FILTER		TAPE AND FILE NUMBERS
SL4-177-5947	whitelight	(A1)	43F8, 9, 10
5953	3581Å	(A3)	45F1
5954	whitelight	(A1)	45F2, 5, 7
5955	OH(3090Å)	(C3)	45F3
5957	whitelight	(A1)	47F1, 5
5958	3581Å	(A3)	47F2
5962	whitelight	(A1)	48F6, 7, 9
5964	C2 emission	(D3)	48F8
5969	3581Å	(A3)	48F1, 4
5970	OH(3090Å)	(C3)	48F2
SL4-178-5987	whitelight	(A1)	48F12, 17 -- 56F2, 3, 4, 5, 6, 7, 21
5988	3581 Å	(A3)	48F 3
5991	OH(3090Å)	(C3)	48F16
5996	whitelight	(A1)	48F10, 17 -- 56F1, 8, 9, 10, 11, 12, 21
6000	OH(3090Å)	(C3)	48F11

Calibration wedges for frames SL4-177-5947-70 -- 56F17, 18, 19, 20
Calibration wedges for frames SL4-178-5987-6000 -- 56F13, 14, 15, 16
SL4-177 is the serial number of cassette BE-08, and SL4-178 is BE-09.

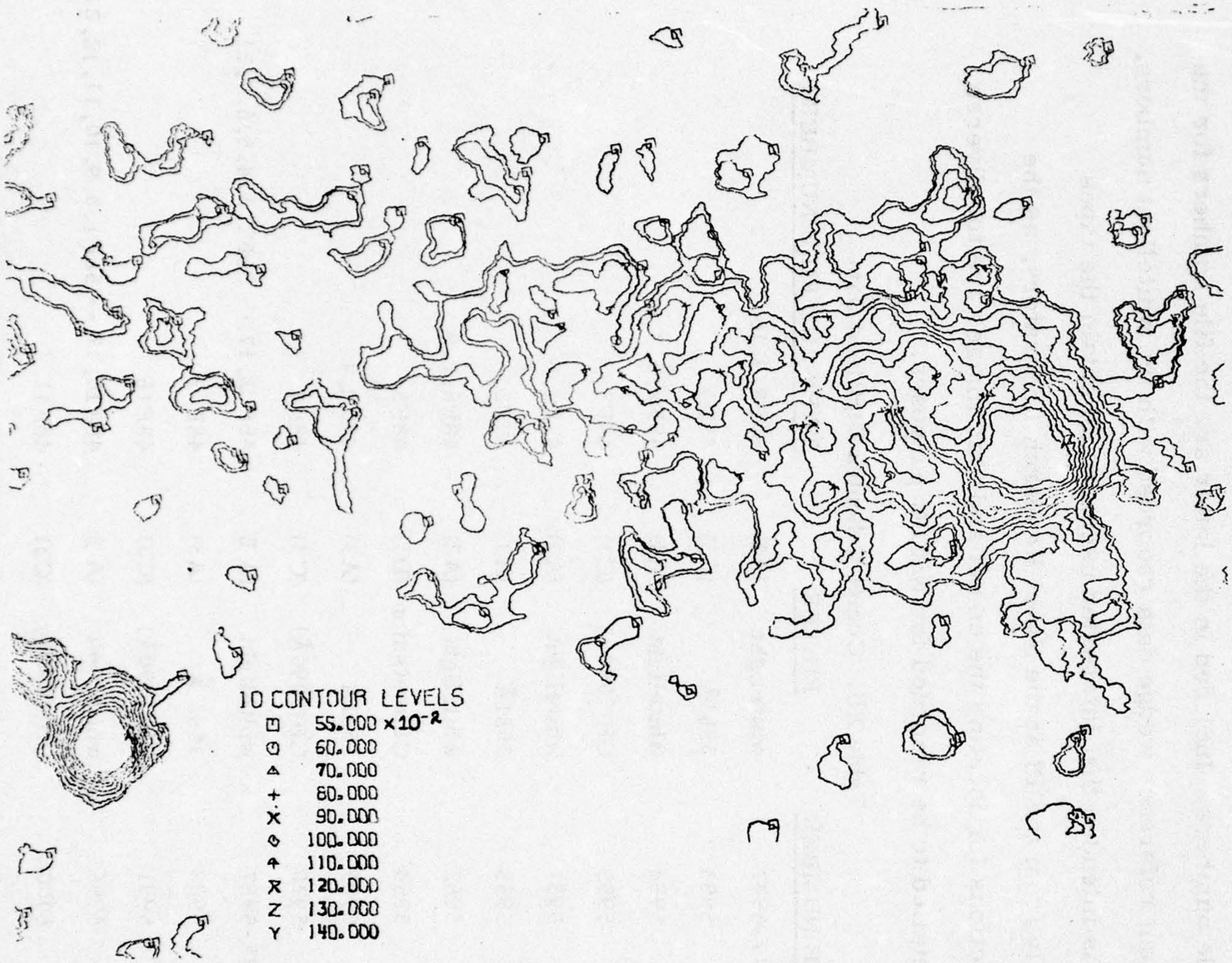


Fig. 11 — Comet Kohoutek, photographed December 9, 1973 (2056 UT) — isodensity plot

PART V

Noctilucent Clouds

Noctilucent clouds occur usually only during the summer months and at high latitudes. They are conjectured to be formed by water vapor condensing on dust, meteoritic debris or whatever in a narrow range of altitude near 82 km. It was expected that the clouds would be readily visible when viewed from space "edge-on," for their angular thickness would be 0.2-0.25 degrees, and they should appear as a thin bright line against the dark sky and below any airglow layers. Being quite tenuous, they would not be detectable, however, against the earth background when the spacecraft passed over them. As the clouds are observed only in summer, the Skylab was expected to be an ideal platform from which to observe and photograph them in the northern hemisphere during SL-3 and in the southern during SL-4. Nothing at all, however, was reported during either mission that could be interpreted as being noctilucent clouds. On SL-4, thirty-four (34) frames of high-speed black and white film were exposed during spacecraft twilight in the south polar region during its seasonal summer. No cloud images were detected on any of these photographs. Furthermore, the astronaut-observers reported that they did not see any at any time during either of the missions. This does not necessarily mean that the clouds were nonexistent, however, because dawn and twilight, the only times the noctilucent clouds could be seen from the spacecraft, lasted less than 5 minutes, and the observers' work schedules were quite full, allowing little time for "sightseeing."

On SL-2, the first manned mission, the Pilot was enthralled by the spectacular views of the earth horizon at all times and especially at twilight when the colors were dramatic. He spent as much time as his duties would permit observing the view from space and saw what must have been noctilucent clouds. From an average of six or so viewing sessions per day, noctilucent clouds were observed a total of about 4 times during the mission. They were seen always at dawn and in the direction of the rising sun, although clouds and sun were never observed together. The clouds were bright, as conjectured, and formed a thin bright line just above the earth horizon when first detected. As the spacecraft approached, the thin line appeared to become broken, and finally 2 to 4 patchy, thin, stratified "clouds" were visible. Their lateral angular subtense was of the order of 5 degrees, and as the spacecraft drew nearer, the clouds appeared to rise above the earth horizon, finally vanishing into the airglow. The sightings were made during the last week in May and the first week in June, 1973, near 50 degrees north latitude and 10-40 degrees east longitude. The astronaut's description agrees well with ground-based observation of altitude and extent of the clouds.

Items Deposited with NSSDC

Part I - Airglow

1 Magnetic Tape #26

1 Roll B and W Film, SL3-131/132/133/134

Part II - Ozone

1 Magnetic Tape #08

1 Magnetic Tape #10

1 Roll B and W Film, SL4-173/205

Part III - Auroras

3 Magnetic Tapes #58A, 58B, 58C

2 Magnetic Tapes #61A, 61B

2 Magnetic Tapes #67A, 67B

1 Roll Color Film, SL3-130/SL4-200

1 Roll B and W Film, SL3-130/SL4-200

Part IV - Comet Kohoutek

1 Roll B and W Film, SL4-177/178/179/180/181

APPENDIX A

Film

All film used on Experiment S063 was 35-mm size and in cartridges of approximately 40 exposures for black and white and 60 exposures for color. All color film was exposed in Nikon camera NK01, all black and white (Tri-X) for Comet Kohoutek in NK04 and all black and white (2485) for airglow and ozone in NK02. All but one roll of black and white film on the last mission (SL-4) were out-of-focus because of a malfunction in NK02. Each frame is identified by mission, roll number and frame number. Each frame and roll number is unique, with no duplication in any other type film or on any other mission, e.g., SL-3-130-3130. This identification number (I.D.) is imprinted upon copies of all flight film but does not appear on the originals. When viewing the film, orient it so that the I.D. is readable at the bottom of the frame. The film will then be as in the camera when viewed from in back of the opened rear loading door. The emulsion side will be on the film side opposite the viewer and the frame numbers will increase from right to left; i.e., from "Heads" end to "Tails" end. In this orientation, the right edge of the frame will be very near the line joining the right sides of the nearest upper and lower sprocket holes. The right side of these holes, for most microdensitometer scans, was taken as $x = o$, and top edge of the lower hole as $y = 0$. Increasing x in micrometers was to the left on the film and plus y toward the top of the frame.

MAGNETIC TAPE

Identification Label at Beginning of Each Record

26F18	3-03	AG133	-	3238	1024	x	112	5 x 100	S128
a	b	c		d	e		f	g	h

a = Magnetic Tape No. and File No

b = Date of tape recording

c = I. D. of film frame, e.g., AG = airglow; 133 = I. D. number of film roll

d = Frame number

e = Number of steps per scan line = number of points per record

f = Number of scan lines = number of records

g = Aperture size in micrometers

h = Speed of scan; S128 is 1/2 max. speed of S255, 40 mm/sec.

REFERENCE WEDGE

A step wedge referred to as REF WEDGE or REF WEG, was scanned at least once per scanning session with each type scanning aperture and was recorded on each magnetic tape so that changes in calibration adjustment of the microdensitometer (PDS) may be corrected to a common basis for all frames. The wedge was an uncalibrated Kodak film with the following characteristics: 21 steps, each 5-mm wide, and ranging in diffuse density from 0.03 to 3.05 with 0.15 density difference between adjacent steps.

Scanning of the reference wedge was done with increasing y values parallel to step boundaries, using the same aperture as for frame

scanning. See Fig. 12. A step was scanned along its middle for a distance of approximately 5.2 mm with no overlapping of steps. Twenty four (24) scans, 5 mm. apart, were made starting at the clear film end with density = 0.03 as the first scan. The density adopted as the value of a step should be a simple average of all the values of a step scan. A least squares fit could easily be done by computer but such accuracy probably is not warranted for most uses of the data. Densities measured with the PDS are highly specular in nature and are always higher than the diffuse densities. Fig. 13 is a typical plot of a diffuse (Macbeth) measurement of a "calibration" wedge, described below, and a PDS measurement.

CALIBRATION WEDGES

Identification of the calibration wedge scans was entered on the magnetic tape labels as "CALWEG 131-1" or "CALWEG 3-133-2", where the numbers 131 and 133 are the film roll numbers and the following 1 or 2 refers to pre- or post-flight step wedge. These sensitometric step wedges were imposed at the end of each roll of black and white film assigned to S063, one before flight and one post flight. The only criterion by which the two are distinguished is that the post-flight wedge densities are higher step-for-step than those of the preflight.

The CALIBRATION WEDGE steps were 3-mm wide and varied from 10-mm to 13-mm long. As the exposures at either end of the wedges were often not proper to show step boundaries, a small opaque triangle was placed on the eleventh (11th) step of the wedge as a telltale. This triangle image was always scanned and its low density should be used

as identification of the eleventh step from the dense side of the scanned wedge image. This step has a diffuse value of log(Relative Exposure) = 1.5.

The calibration wedge was scanned, with the same aperture used for frame scanning, parallel to the step boundaries for a distance of 10 mm to 13 mm. See Fig. 14. There were 3 scans per wedge step with one scan in the middle and two spaced 1 mm either side of the middle scan. These three scans should be averaged.

It is recommended that all density values in a scan be printed and those departing appreciably from the average discarded. This is because there were too many artifacts in each wedge image to list here individually.

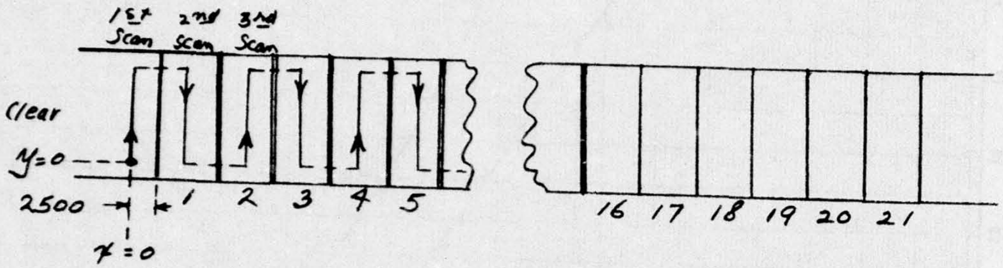
COLOR CALIBRATION WEDGE

Identification on the magnetic tape labels of the color wedge scans are "CALWEG 130", "CALWEG4-200", "CALWEGBLU-200", and "CALRED-130", etc. Color film was used only for auroral and lower atmosphere horizon scenes.

For densitometry purposes, a panchromatic film was used to make copies of the color flight film. Sensitometric step wedges were not put on the original color film before development, so that, in order to have some measure of correlation between density and intensity on the black and white copy, a neutral density step wedge was imposed on the first generation color film. The step wedge was then transferred from this color-copy film to the black and white copy. This procedure was makeshift at best but it did result in a density-log (Relative

Exposure) relationship from which relative intensities in the black and white copy could be derived. It is hoped, of course, that the intensity transfer was one-to-one from the original color film to the black and white film regardless of color.

Only two color film rolls were involved in the above, SL3-130 and SL4-200. The black and white wedge identification is simply CALWEG 130 and CALWEG4-200. Some frames of each color roll were digitized using three color separation filters, red, green and blue. The wedge on the color film was also scanned using the filters. These scans are identified as CALBLU(RED or GRN)130 - and CALWEGBLU(RED or GRN)4-200. The scan pattern is shown in Fig. 15.



21 steps, each 5mm. wide

Scan start at clear end

y-scan

x step = 5000 μm

y step = aperture

No. of scans = 24 (1 scan/step + 2)

Fig. 12 — Reference wedge

DATE 2-28-74 CONTROL # R 35mm TASK Original Pre PREPARED BY BV50

FILM 2485 EMULSION # 108-5 MFG EK EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR Hi-Speed	INSTRUMENT MacBeth	SPEED
ILLUMINANT 2850 °K	CHEMISTRY D-19	TYPE TD504	D-MAX
TIME 1/100 SEC	SPEED TANKS 5 FPM	APERTURE SIZE 3 MM	GAMMA
FILTER 5500°K + 1.0ND	TEMP F 85 TIME	FILTER Visual	BASE - FOG

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KBr

21	2.23
20	2.20
19	2.17
18	2.15
17	2.03
16	1.94
15	1.87
14	1.75
13	1.64
12	1.59
11	1.48
10	1.40
9	1.33
8	1.30
7	1.27
6	1.26
5	1.26
4	1.25
3	1.25
2	1.25
1	1.25

Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

-10

mcs ergs/cm²

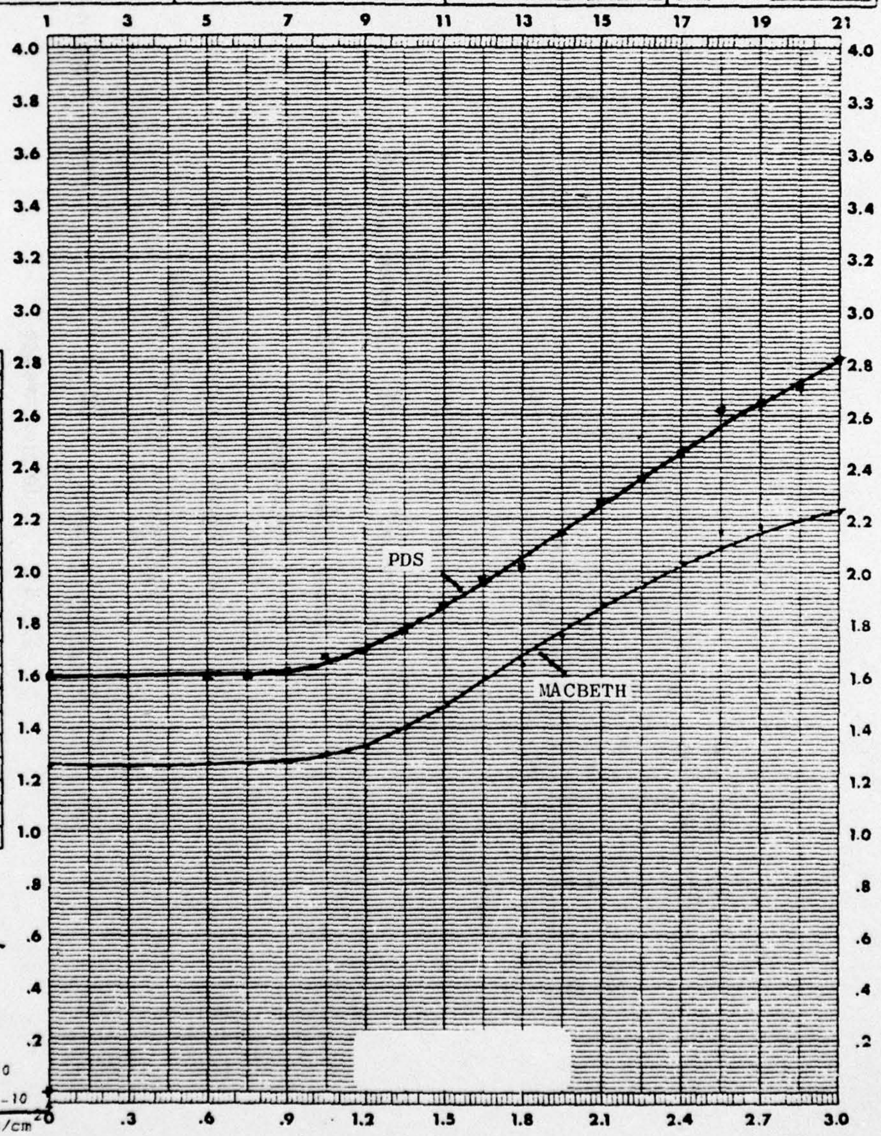


Figure 13

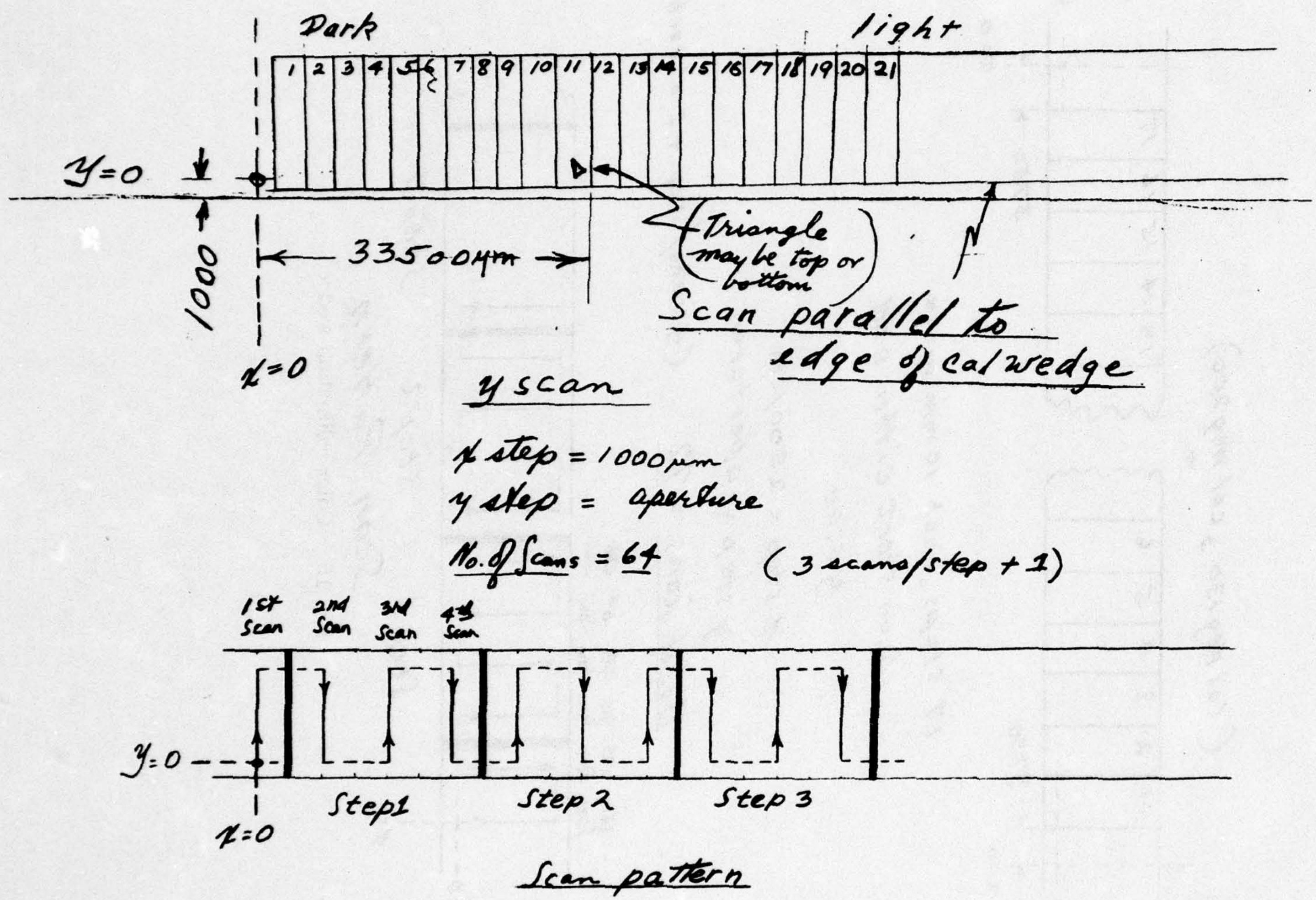
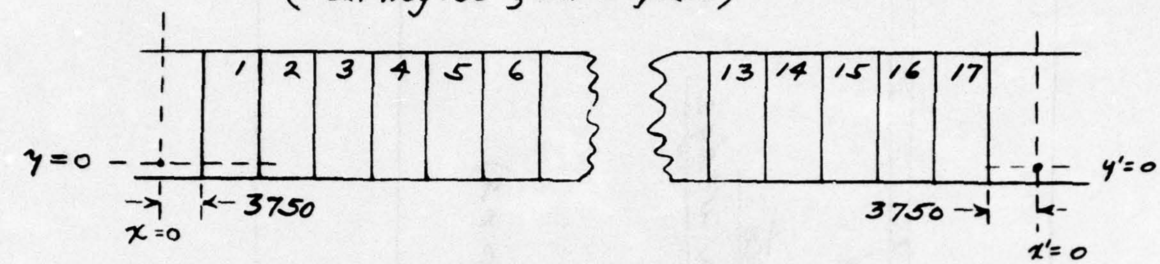


Fig. 14 — Calibration stepwedge at end of film roll

(Cal Weg 130, cal Weg 200)



17 steps, each 10mm wide

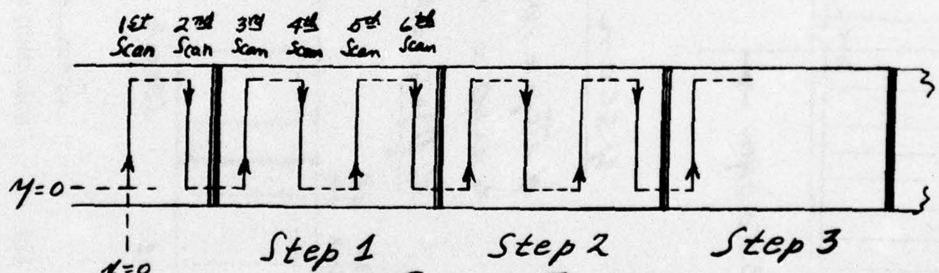
Scan start either end

y scan

x step = 2500μm

y step = aperture

<u>No. of Scans</u> = <u>72</u> (4 scans/step + 2 at each end)



Scan Pattern

Fig. 15 — Color calibration wedge

APPENDIX B

Magnetic Tape Format

The technical details of the magnetic tape format used in the recording of Experiment S063 digitized data are presented in the accompanying copy of a manual issued by the Perkin-Elmer Corp.

Magnetic tapes deposited with the NSSDC are copies of the original and are all recorded on 7 tracks at 556 bits per inch. Each record contains one scan line, and a file mark is placed at the end of each complete frame scan. Four file marks indicate end of recording on a tape.

The mechanical movement of the scanning table of the micro-densitometer (PDS) is back and forth; i.e., at the end of a scan line, the table stops, moves over to the next scan line and then scans in the direction opposite to the just-completed scan. In a Type R Scan, the data are recorded on tape in the order taken. In the Type F Scan, the scanning remains the same mechanically, but the computer reverses the order of the data of all even-numbered scans before transferring them to the magnetic tape. Thus in the Type F scan, the data are ordered as for a television type raster scan, each line starting at the same side of the frame. Magnetic tapes numbered 01 through 40 are Type R scans. Starting with tape 41, all the remainder of tapes are Type F scans.

OUTPUT DESCRIPTION

Magnetic Tape Format

Scansalot Program

Recording Information

Channels	7	9
Bits/Inch	556	800
Parity	Odd	Odd

File and interrecord gaps are IBM compatible.

Digit Representation

Figure 16 illustrates the relevant 7- and 9-track allocations and spacings. Note that in the 9-track system consecutive data channels are not allocated to consecutive tracks.

Character Contents

Each tape character has been recorded to represent six binary bits of information. Thus, in the 9-track system, channels 0 and 1 do not contain meaningful information and should be discarded during data reduction.

Data Format

The contents of each data record are as follows:

I Two tape characters representing the octal number 7777. These are used for the purpose of recognizing the beginning of a record. They are not part of the program data.

II Eighty characters representing forty 12-bit words of sample identification information. Each pair of characters contains

the ASCII code for one identification word.

e.g. The 2 tape characters (000011) (000001) would produce the octal number 0301, which is ASCII code for the letter A.

III Two characters representing the octal value for minus the number of data values following the coordinate information in the record.

Each data value will be comprised of two tape characters, making one 12-bit word.

e.g. The two tape characters (110000) (000000) = 6000 = - 2000 would represent the fact that there are 2000 data values following the coordinate information in this record.

IV Four characters representing a 24-bit binary number which is the X coordinate on the sample (in micrometers) when data taking begins for the current data record. The most significant bit is a sign bit.

If the sign bit is a one, the coordinate value represented has a negative value. The binary absolute value of the coordinate, in this case, is found by twos complementing the 24-digit number and incrementing the result by one.

e.g. The tape characters (000000) (000010) (011100) (010000) represent the coordinate + 00023420 = + 10000 microns. The tape characters (111111) (111101) (100011) (110000) represent the coordinate - 00023420 = - 10000 microns.

V Four characters representing a 24-bit binary number which is the Y coordinate on the sample (in micrometers) where data taking begins for the current data record. Interpretation is the same as explained above for X.

VI Four characters representing a 24-bit binary number which is the X distance (in micrometers) between density (or transmission) readings. Interpretation is the same as explained above for X and Y.

VII The remaining characters in the record should be broken into groups of 2 characters each. Each group of 2 represents one density (or transmission) reading from the sample. To interpret the values, do the following:

Use 2 tape characters to obtain a 12-bit binary number. Convert the number to decimal. Divide by 400.0. The result is the desired density (or transmission) value.

e.g. The 2 tape characters (000111) (110100) represent the number

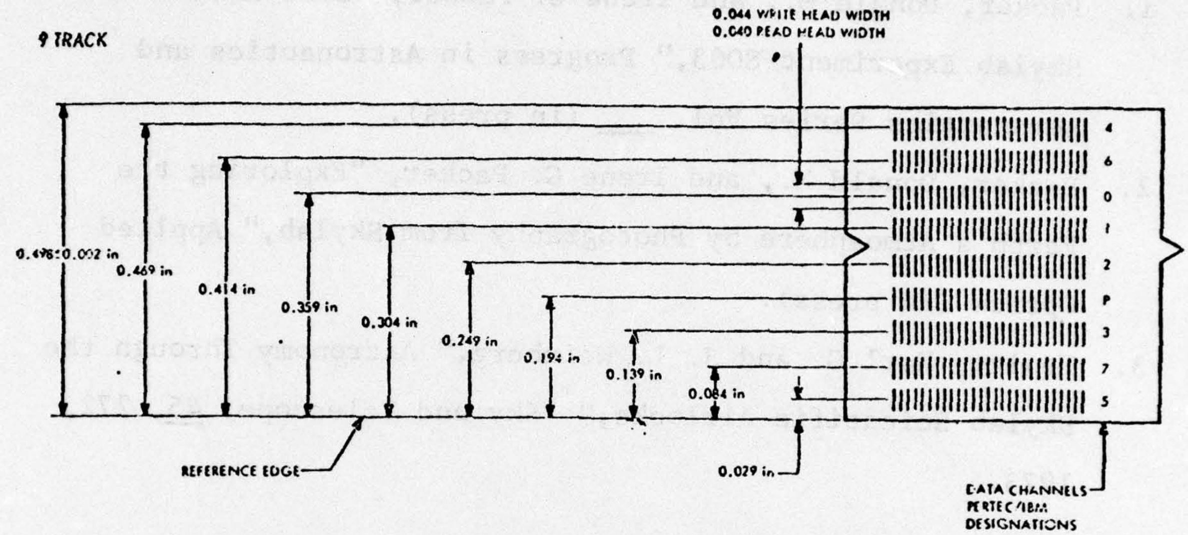
764 = 500 .

Then 500/400.0 = 1.25 (density value).

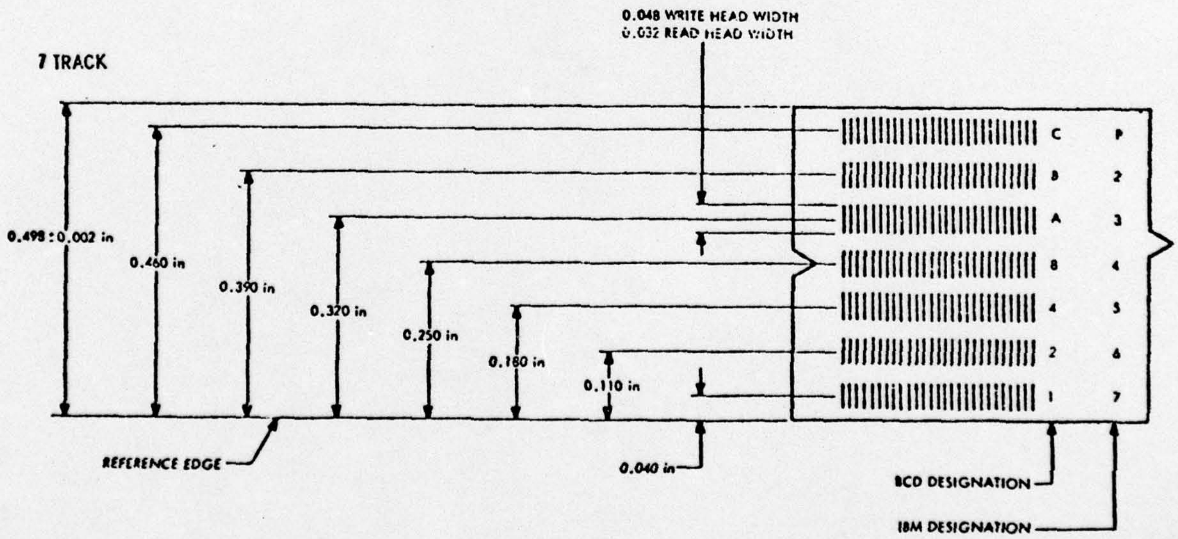
This completes the record contents.

Between any two data records for a given sample there is an interrecord gap.

Following the last data record for a given sample is a file gap.



9-track allocation and spacing



7-track allocation and spacing

Figure 16

REFERENCES

1. Packer, Donald M., and Irene G. Packer, "Some Results of Skylab Experiment S063," Progress in Astronautics and Aeronautics Series Vol. ___ (in press).

2. Packer, Donald M., and Irene G. Packer, "Exploring the Earth's Atmosphere by Photography from Skylab," Applied Optics (in press).

3. Henize, Karl G. and J. L. Weinberg," Astronomy Through the Skylab Scientific Airlocks," Sky and Telescope, 45, 272, 1973.

References and Reports

1. Packer, Donald M., Acceptance Test Procedures for UV Airglow Horizon Photography (Skylab Experiment No. SO63), NRL-7141-63-001-I, September 1971.
2. Packer, Donald M., Preliminary Report, Cleaning Kits for Skylab Experiment Optics, Effects of Lens Tissue and Anti-fogging Material on Ultraviolet Transmittance of Optics, NRL-7141-63-002-I, 7 October 1971.
3. Henize, Karl G., and J. L. Weinberg, Astronomy through the Skylab Scientific Airlocks, Sky and Telescope 45, 272-276, 1973.
4. Packer, Donald M., and Irene G. Packer, Preliminary Report for Skylab Experiment SO63, "UV Airglow Horizon Photography", Second Skylab Mission August-September 1973, 26 October 1973.
5. Packer, Donald M., and Irene G. Packer, Preliminary Experiment Report for Skylab Experiment SO63, "UV Airglow Horizon Photography", Skylab Missions SL-3 and SL-4, 1973-1974.
6. Packer, Donald M., and Irene G. Packer, Final Report, Skylab Experiment SO63, "UV Airglow Horizon Photography", December 31, 1975.

7. Packer, Donald M., and Irene G. Packer, Some Results of Skylab Experiment SO63, Progress in Astronautics and Aeronautics, Vol. 48 (in press).

8. Packer, Donald M., and Irene G. Packer, Exploring the Earth's Atmosphere by Photography from Skylab, Applied Optics (in press).

9. Packer, Donald M., Observations of Kohoutek, Chap. IV of NASA book, "Astronomy and Space Sciences", (in press).

10. Packer, Donald M., Aurora, Chap. VI of NASA book, "Astronomy and Space Sciences" (in press).